I-70 East

Hydrology and Hydraulics Technical Report Addendum

January
2016

I-70 East Final Environmental Impact Statement

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LIST OF ACRONYMS

CBC	Concrete box culvert
cfs	Cubic feet per second
Denver	City and County of Denver
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
DSDMP	Denver Storm Drain Master Plan
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
MS4	Municipal Separate Storm Sewer System
RCP	Reinforced concrete pipe
RTD	Regional Transportation District
UPRR	Union Pacific Railroad

1 PURPOSE OF THIS REPORT

This addendum supports the Hydrology and Hydraulics Technical Report prepared in August 2014 for the I-70 East Supplemental Draft Environmental Impact Statement (EIS). It presents the environmental impacts of the Preferred Alternative (Partial Cover Lowered Alternative with Managed Lanes Option) and compares its effects to those of the No-Action Alternative and Revised Viaduct Alternative, as discussed in the Supplemental Draft EIS. The Partial Cover Lowered Alternative with General-Purpose Lanes Option is discussed only where impacts differ from the Preferred Alternative.

The information contained in the previous technical report is still pertinent to the No-Action Alternative and Revised Viaduct Alternative and their associated effects, except where this addendum specifically revises these alternatives. Updated text has been cross-referenced using the page numbers contained within the 2014 Hydrology and Hydraulics Technical Report. Where an addendum figure or table updates or adds new data and/or different potential effects to an exhibit contained in the technical report, the figure or table name is followed by "(Update to Figure/Table # of the 2014 Technical Report)."

An errata sheet is included in this addendum to show revisions and clarifications to the 2014 Hydrology and Hydraulics Technical Report.

2 ALTERNATIVES UNDER CONSIDERATION

The Final EIS fully evaluates the No-Action Alternative, Revised Viaduct Alternative, and Partial Cover Lowered Alternative for impacts to the hydrology and hydraulics of the project area. Descriptions of the No-Action Alternative and Revised Viaduct Alternative are included in the August 2014 Hydrology and Hydraulics Technical Report. The Partial Cover Lowered Alternative is referred to hereinafter as the Preferred Alternative, and is described in the following subsection. A description of the phasing for the Preferred Alternative also is detailed.

2.1 Preferred Alternative

As a result of the comments received on the Supplemental Draft EIS and additional stakeholder outreach and agency coordination, the Partial Cover Lowered Alternative has been refined to include elements of both the Basic and the Modified Connectivity Options of the Partial Cover Lowered Alternative as they were analyzed in the Supplemental Draft EIS. This document includes updated analysis of the refined Partial Cover Lowered Alternative and does not include multiple Connectivity Options.

The Partial Cover Lowered Alternative as it is presented in the Final EIS removes the existing I-70 viaduct between Brighton Boulevard and Colorado Boulevard, lowering the highway below grade in this area. It adds additional lane(s) in each direction from Brighton Boulevard to Tower Road. It also adds capacity from I-25 to Brighton Boulevard by restriping.

This alternative includes a cover over the highway in the vicinity of Clayton Street and Columbine Street. As part of this alternative, 46th Avenue will be located on the north and south sides of the highway. It will be a two-way street between Josephine Street and Milwaukee Street on both sides of the highway and one way in the other locations. This alternative eliminates the portion of 46th Avenue north of I-70 between Columbine Street and Clayton Street to allow for a seamless connection between Swansea Elementary School and the highway cover. As part of this alternative, access to and from I-70 at the Steele Street/Vasquez Boulevard interchange is maintained.

Lowering I-70 requires capturing offsite surface runoff that currently flows south to north. The offsite drainage system included in this alternative is designed to prevent the lowered section of I-70 from flooding. This storm drain system will be conveyed south of I-70 through Globeville Landing Park and discharge to the South Platte River. Additionally, an onsite drainage system is designed north of I-70 to drain runoff from the highway.

The Preferred Alternative includes an overall approach to design and construction that technically would not preclude for the construction of a second cover over the highway from west of the Steele Street/Vasquez Boulevard highway crossing to east of Cook Street. This second cover will not be included as a part of the Preferred Alternative.

The Operational Options of the Partial Cover Lowered Alternative—General-Purpose Lanes and Managed Lanes—remain the same as those analyzed in the Supplemental Draft EIS. They include two scenarios about how the additional capacity with the Build Alternatives will be managed and operated. The General-Purpose Lanes Option will allow all vehicles to use all the lanes on the highway with no restrictions, while the Managed Lanes Option implements operational strategies (such as pricing) for only the additional lanes while keeping the rest as general-purpose lanes. With the Managed Lanes Option, the additional lanes are separated from the general-purpose lanes with a striped buffer and direct connections from the managed lanes to I-225, I-270, and Peña Boulevard are provided.

The Partial Cover Lowered Alternative with Managed Lanes Option is identified as the Preferred Alternative for this project. For more details on the Preferred Alternative, refer to Chapter 3, Summary of Project Alternatives, in the Final EIS.

2.2 Phasing of the Preferred Alternative

Revenue sources for the I-70 East project include allocations from various state and local sources, but there remains a gap between the estimated cost of the project and the revenue available to build it. Because of these funding limitations, the project will be constructed in phases over time. Phase 1 is the only defined phase for the project at this time. Future phases have not been determined and will rely on future funding; therefore, any future phases are referred to as Phase 2.

2.3 Phase 1

Phase 1 incorporates portions of the identified Preferred Alternative, the Partial Cover Lowered Alternative with Managed Lanes Option. It includes all construction and mitigation

commitments included in the Preferred Alternative from Brighton Boulevard to Chambers Road.

In general, Phase 1 includes the complete reconstruction of I-70 from Brighton Boulevard to I-270 with pavement width for the addition of two lanes in each direction. Only one lane will be open for use until traffic demand is met to open the second lane. It also includes widening the remaining stretch from I-270 to Chambers Road to accommodate one additional lane in each direction and restriping from I-25 to Brighton Boulevard.

Phase 1 includes the construction of the highway cover between the Clayton Street and Columbine Street bridges and the associated urban landscape area on the cover. It will reconstruct the frontage roads, 46th Avenue North and South between Brighton Boulevard and Colorado Boulevard and Stapleton Drive North and South between Colorado Boulevard and Quebec Street. Phase 1 also includes the drainage requirements from the Preferred Alternative.

Similar to the Preferred Alternative, Phase 1 includes an overall approach to design and construction that technically would not preclude construction of a second cover over the highway from west of the Steele Street/Vasquez Boulevard interchange to east of Cook Street. However, this second cover will not be included as part of the Preferred Alternative or Phase 1.

2.4 Phase 2

Phase 2 incorporates the remaining improvements needed for the Preferred Alternative. This phase would stripe in an additional tolled express lane from Brighton Boulevard to Quebec Street—Phase 1 constructed this section of I-70 wide enough to accommodate the additional lane.

From Quebec Street to Chambers Road, I-70 would be widened for an additional tolled express lane in each direction, one going eastbound and one going westbound. From Chambers Road to Tower Road, capacity is increased by widening to accommodate additional tolled express lanes. Three proposed direct connections are planned from the tolled express lanes to I-270, I-225, and Peña Boulevard to accommodate regional and airport traffic. These direct connections result in a shift of eastbound I-70 to create room for the connections.

3 CHANGES TO APPLICABLE LAWS, REGULATIONS, AND GUIDANCE

There have not been any changes to the applicable laws, regulations, or guidance since the 2014 Hydrology and Hydraulics Technical Report.

4 CHANGES TO EXISTING CONDITIONS

The 2014 Hydrology and Hydraulics Technical Report provides a detailed discussion of the existing conditions in the Hydrology and Hydraulics study area. There have not been any changes or data updates to existing conditions for Hydrology and Hydraulics.

5 EFFECTS ANALYSIS

There have not been any changes to the analysis since the 2014 Hydrology and Hydraulics Technical Report.

6 MITIGATION

The 2014 Hydrology and Hydraulics Technical Report provides a detailed discussion of the required and proposed mitigation measures planned for the project. The changes to the mitigation measures from the 2014 Hydrology and Hydraulics Technical Report are discussed below.

6.1 Potential Mitigation

Hydrologic analysis of the project alternatives used available studies to determine peak flows impacting the project. Future hydrologic studies may become available as design of the project alternatives advances. Preliminary design of the proposed storm drainage systems used available information to identify potential solutions to onsite and offsite drainage issues.

The existing offsite drainage (surface flows) is not anticipated to be impacted or changed by the No-Action Alternative or the Revised Viaduct Alternative. Onsite drainage flows (within the construction limits) will be changed due to all of the alternatives. For the No-Action Alternative or the Revised Viaduct Alternative, the increased width of the viaduct increases the amount of runoff from the I-70 viaduct. Improvements to properly address storm drainage runoff will be necessary, with specific water quality measures to conform to the municipal separate storm sewer system (MS4) requirements. Detention structures may be required to mitigate the additional width of the proposed viaduct structures. Additionally, an onsite drainage outfall system is proposed to convey runoff from the No-Action Alternative and Revised Viaduct Alternative directly to the South Platte River and reduce the runoff draining into the existing urban ponding area. This outfall will not change the boundary of the existing South Platte River floodplain.

With the Partial Cover Lowered Alternative, the highway will be below grade between Brighton Boulevard and Colorado Boulevard; therefore, both onsite drainage and offsite drainage design will have to be implemented. The following sections discuss the offsite and onsite improvements associated with the Partial Cover Lowered Alternative.

6.2 Offsite Drainage System

The Partial Cover Lowered Alternative consists of removing the I-70 viaduct between Brighton Boulevard and Colorado Boulevard and constructing I-70 below the existing ground elevation, referred to as the lowered section. This lowered section includes a low point near the Union Pacific Railroad (UPRR) crossing. The purpose of the offsite drainage system is to prevent the existing offsite flows from draining into the lowered section of I-70. The offsite drainage system is designed to convey a 100-year storm event flow, which is required for an interstate facility. The offsite drainage system is shown in Appendix D.

The I-70 Partial Cover Lowered Alternative alignment was divided into three sections, as discussed in detail in the following subsections.

6.2.1 Section 1—Dahlia Street to Colorado Boulevard

The flow impacting this section of I-70 East to the east of Colorado Boulevard was referenced from the *Memorandum for I-70 PCL Park Hill Drainage Basin Hydrologic Analysis* (Enginuity, 2014).

A series of two detention ponds are proposed in the vicinity of the Colorado Boulevard interchange (see Figure 1):

- Pond 1: Located in the southeast quadrant
- Pond 2: Located in the northeast quadrant

The purpose of Pond 1 and Pond 2 located at Colorado Boulevard is to capture and attenuate the flow discharging into the existing Denver Storm Drain Master Plan (DSDMP) facility on 48th Avenue. The two detention ponds are connected with a large culvert under I-70 East to the east of Colorado Boulevard. Pond 2 discharges into a proposed 72-inch reinforced concrete pipe (RCP) that drains to the north and connects into an existing DSDMP facility located on 48th Avenue. Pond 2 will be designed to overtop in the 100-year storm and the flow will follow the existing flow path established in the *Memorandum for I-70 PCL Park Hill Drainage Basin Hydrologic Analysis* (Enginuity, 2014).

The 100-year flow impacting this section of I-70 East is 2,106 cubic feet per second (cfs). The flow will be conveyed to the west via a proposed storm drain system and surface flow along 46th Avenue into Pond 1, located in the southeast quadrant of the Colorado Boulevard interchange. The purpose of the proposed storm drain along 46th Avenue is to prevent flow from draining into the lowered section of I-70 East and to ensure that the widening of I-70 East does not have an adverse impact on the properties to the south. The existing 10-foot x four-foot concrete box culvert (CBC) that is located adjacent to the light rail to the south of the Safeway Distribution Center at Colorado Boulevard will be cut off and drained into Pond 1.

6.2.2 Section 2—Colorado Boulevard to York Street

The flow impacting I-70 East from Colorado Boulevard to York Street is generated from local basin flow. The proposed drainage system required to protect the I-70 East lowered area from offsite flows for the section between Colorado Boulevard to York Street is described below.

A proposed storm drain located along 46th Avenue begins at the historic low point commonly known as the Market Lead railroad crossing, which is located to the east of Madison Street at the UPRR crossing. The proposed storm drain conveys flow to the west into Pond 3 located in the southeast quadrant of the Steele Street/Vasquez Boulevard interchange that discharges into Pond 4 located in the southwest quadrant of the Steele Street/Vasquez Boulevard interchange. Pond 4 discharges into a proposed storm drain system located along 46th Avenue that conveys the flow to the west into Pond 6 located at York Street.

Pond 5 is located in the northeast quadrant of the Steele Street/Vasquez Boulevard interchange. Its purpose is to capture and attenuate the flows draining to the south adjacent to Steele Street/Vasquez Boulevard.

The drainage design for this section takes into account the capacity of the existing DSDMP facility along 45th Avenue and the existing 72-inch RCP located along York Street. A proposed storm drain bridge over the I-70 East lowered section splitting the flows to the north (72-inch RCP Bridge) and to the west (proposed drainage system to South Platte River) at Pond 6 located to the east of York Street will take place to match historic flow patterns. Figure 2 shows the location of the proposed detention ponds in the vicinity of the UPRR crossing at Market Lead.

6.2.3 Section 3—York Street to South Platte River

The flow impacting I-70 between York Street and the South Platte River is referenced from the *Memorandum for I-70 PCL Montclair Drainage Basin Hydrologic Analysis* (Enginuity, 2014). The Montclair study analyzed this stretch of I-70 with a two-dimensional model and determined the 100-year flow of 2,852 cfs would reach this section of I-70, between Brighton Boulevard and the Union Pacific Railroad.

To capture the offsite flow before it would enter the I-70 lowered section, Pond 7, Pond 7A, and a storm drain sized to convey the discharge are proposed. The purpose of Pond 7 and Pond 7A is to capture the large surface flows draining to this area. The outlet storm drain from Pond 7A is routed to the south of the Denver Coliseum building underneath the parking lot and through Globeville Landing Park to discharge into the South Platte River.

Figure 1. Detention ponds in the vicinity of Colorado Boulevard

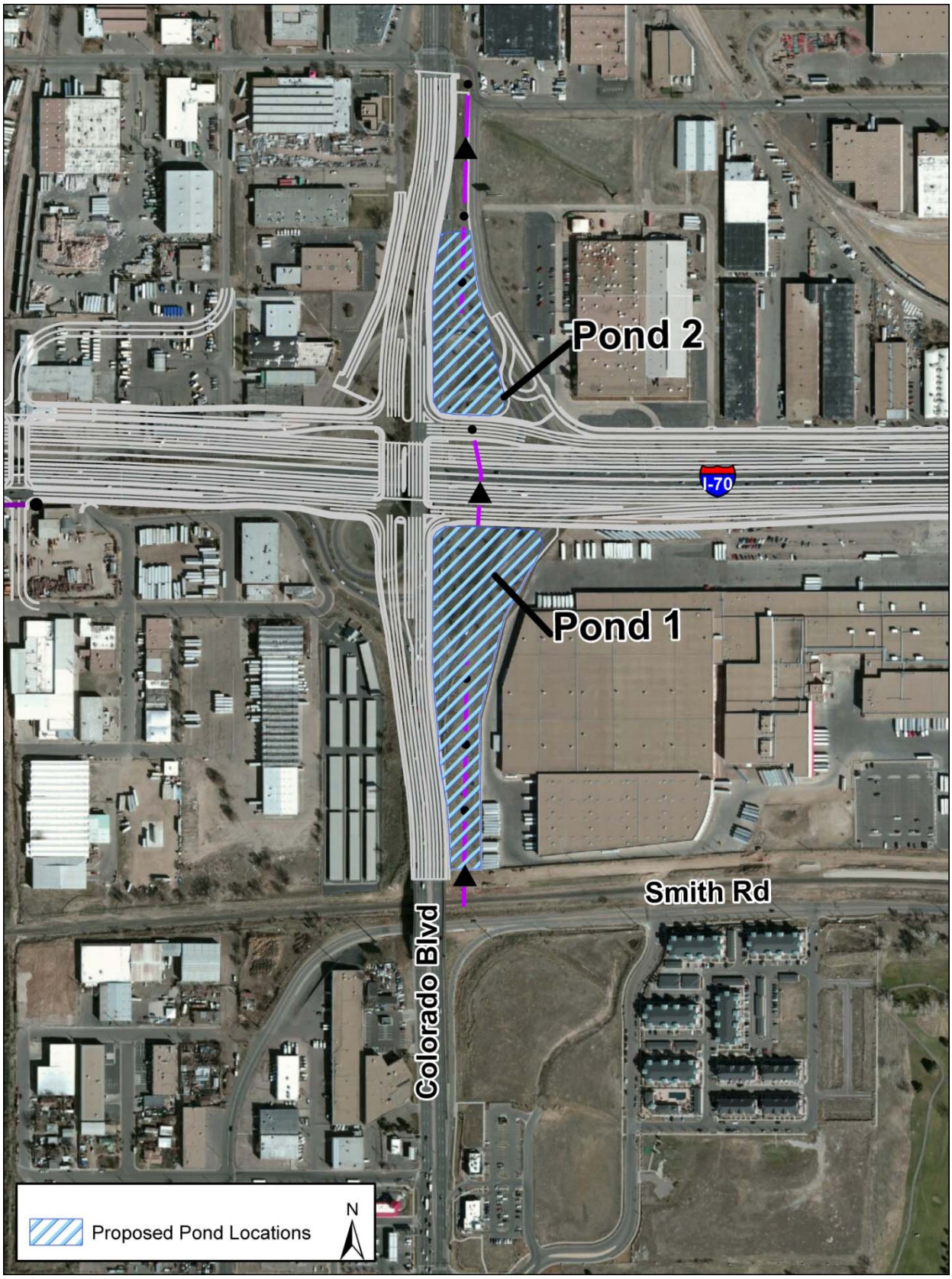
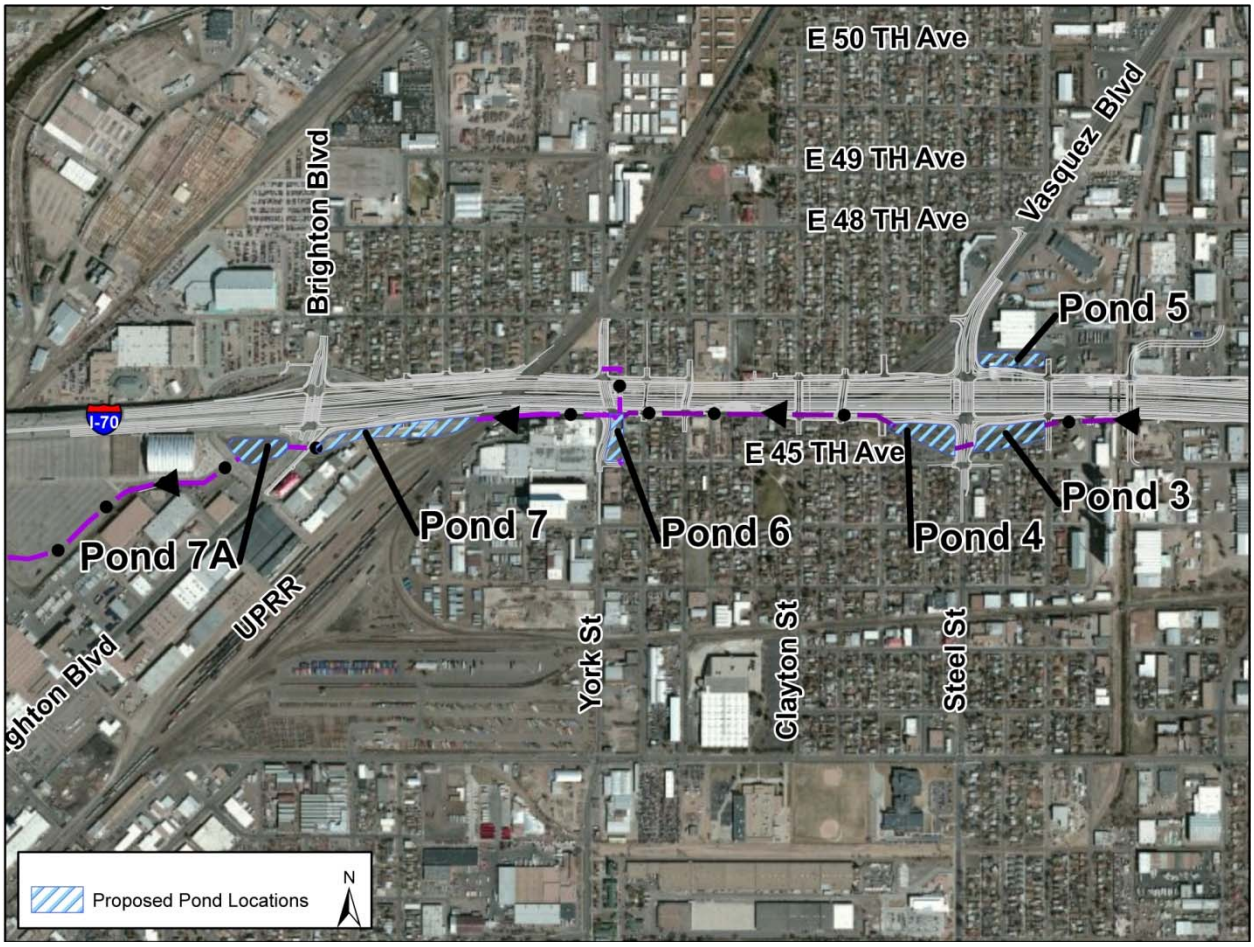


Figure 2. Detention ponds in the vicinity of UPRR



A memorandum dated August 1, 2013, was provided to Denver that documented the offsite flows used to prepare the preliminary design of the Partial Cover Lowered Alternative offsite storm drain system. The lower Montclair basin flows have been changed per the *Memorandum for I-70 PCL Montclair Drainage Basin Hydrologic Analysis* (Enginuity, 2014). This memorandum is included in Appendix B.

6.3 Temporary and Permanent Groundwater Dewatering

The necessary design and infrastructure needed for temporary construction groundwater dewatering and for permanent groundwater dewatering will be developed in the final design and coordinated with the geotechnical design/analysis. Below are three options for groundwater dewatering:

- Horizontal drains
- Drainage gallery with radial drain holes
- Staged well locations and pump system

The groundwater dewatering system will be designed according to the groundwater discharge permit and the water will be treated as necessary. It is not anticipated that discharge due to groundwater dewatering will be conveyed in the surface stormwater drainage system.

6.4 Mitigation Commitments for the Preferred Alternative by Phase

Mitigation measures for the Phase 1 project will include all mitigation identified for the Preferred Alternative as documented in the Final EIS.

7 REFERENCES

Enginuity. (2014). *I-70 PCL Montclair Drainage Basin Hydrologic Analysis.* Denver: Authors.

Enginuity. (2014). *I-70 PCL Park Hill Drainage Basin Hydrologic Analysis.* Denver: Authors.

8 HYDROLOGY AND HYDRAULICS TECHNICAL REPORT ERRATA

The following revisions and clarifications to the Hydrology and Hydraulics Technical Report of the I-70 East Supplemental Draft EIS do not constitute new findings or analysis. The bold text includes new information compared to the Supplemental Draft EIS version.

Section 4.2, pages 4 and 5, should read as follows:

4.2 Applicable Guidance

All drainage design work associated with the I-70 East project would be performed in compliance with the following technical guidance:

- CDOT *Drainage Design Manual* (2004)
- CDOT Municipal Separate Storm Sewer Permit (2008)
- FHWA *Roadside Design Guidelines* (2003), based upon the American Association of State and Highway Transportation Official's *Roadside Design Guide* (2002)
- Denver *Storm Drainage Design and Technical Criteria Manual* (Denver Wastewater Management Division [WMD], 2006, **Amended 2013**)
- Urban Drainage and Flood Control District (UDFCD) *Urban Storm Drainage Criteria Manual* (2001, **Revised 2008, 2013**)
- *City of Aurora Storm Drainage & Technical Criteria* (2005)
- *City of Commerce City Drainage Criteria Manual* (n.d.)
- *Adams County Storm Drainage Design and Stormwater Quality Regulations* (2001)
- *Arapahoe County Draft Stormwater Management Manual* (2012)
- Union Pacific Railroad *Hydraulic Design Criteria* (2003)

In addition, stormwater requirements for the following agencies would be incorporated, as necessary:

- Denver Water Board
- Colorado Water Conservation Board
- Colorado Department of Public Health and Environment

In locations subject to the design criteria of two or more entities, the most stringent criteria would be applied to the project design, unless otherwise noted.

Section 5.2.1, page 6, should read as follows:

5.2.1 Regulated Floodplains and Major Drainageways

Flooding of regulated floodplains and major drainageways in the corridor occurs at areas where the 100-year flows in the drainageways are channeled through structures (bridges and culverts). This produces a backwater effect that can cause the water surface upstream of the structures to rise, spread out, and produce flooding in the vicinity of the crossing. In some cases, the existing structures do not have the capacity for the 100-year flows, and the water overtops the structures, substantially increasing the flooding limits at the structure and for areas downstream.

The flows and hydraulics of the existing structures have been analyzed by FEMA and UDFCD in various flood insurance studies (FIS), flood hazard area delineations, and outfall system planning studies. The resulting flooding limits have been designated as

regulatory "Floodplains and Floodways," and are shown on the current FIRMs published by FEMA. The floodplains and floodways in the project area, identified as SFHAs, are shown in Figure 2.

Improvements to the drainageways and structures within the SFHA are subject to FEMA policy and regulations. The SFHAs require rigorous hydraulic modeling to accurately determine the effects of the new construction on the existing regulatory base flood elevation (BFE) and the floodplain and/or floodway. Generally, these regulations allow for increases in the BFEs of 0 to 1 foot, depending on the type of flood zone. In cases where the BFE is increased, a CLOMR—followed by a LOMR—may have to be obtained from FEMA. **The State's Rules & Regulations for Regulatory Floodplains in Colorado (Nov. 17, 2010), specifically Rule 12.J. that requires a LOMR where there are BFE increases or decreases in excess of 0.3', regardless of whether a CLOMR (CLOMR is required by NFIP regulations for any BFE increase) has been applied for, would be in effect.**

The CLOMR/LOMR process is a regulatory procedure that allows FEMA to review and examine the hydraulic models and proposed improvements. FEMA then determines if the floodplain changes are acceptable (e.g., increased flooding does not result in increased property damage or result in structures being placed in the regulated floodplain). If there is no increase in the BFE, then the analysis should be submitted to the governing agencies to verify that the CLOMR/LOMR process is not necessary.

Section 5.2.3, pages 7 and 8, should read as follows:

5.2.3 Major Flood Events

Flooding in Denver typically is due to short-duration, high-intensity precipitation events that occur between May and September. Denver has a documented history of significant flood events for the period of May 1844 to September 2013. Flooding in Aurora and Adams County is similar to that in Denver. These events show the seriousness of floods in this area and the need for proper design and anticipation of probable large storm events. The following major flood events occurred in the project area:

- On September 9 to 16, 2013, a complex weather pattern produced torrential rain along the Front Range of Colorado, unleashing deadly flash floods in and near the foothills, which lead to a major river flood event for the South Platte River valley.
- On July 19, 1997, a severe thunderstorm in northeast Denver and northwest Aurora yielded 3.83 inches of rain in less than an hour, surpassing the old 1-hour record by more than 1.5 On May 5 and 6, 1973, the South Platte Basin experienced a storm event that brought as much as 6 inches of rain to the area. This caused major flooding during the next two weeks along Clear Creek, Sand Creek, and the South Platte River. The damages from this flood event were estimated at around $120 million.

- **On June 16, 1965—now known as Black Wednesday, the day Denver was hit by the worst natural disaster in the City's history—a cloudburst dumped 15 inches of water on mountain slopes southwest of Denver. A devastating flood struck 20 counties, including Denver along the South Platte River. Twenty-five people were killed, and property damage was estimated at more than $500 million. Since that time, Chatfield and Bear Creek Dams have been constructed, greatly reducing the flood threat to Denver from precipitation over major sub-drainage basins.**
- On July 23 and 24, 1965, heavy rain fell over Denver and Aurora, washing out earthen bridges over Sand Creek and causing flooding of roads, streets, and bridges.
- On May 8 and 9, 1957, more than 4 inches of rainfall fell in a storm over eastern Colorado around Sand Creek. The floodwaters from this storm receded along Sand Creek within 12 hours, but still produced a discharge of approximately 25,000 cubic feet per second (cfs) at Stapleton International Airport. Most of the damages from this event were due to erosion undercutting houses, damaging bridges, and eroding railway embankments.
- In May 1948, a storm produced 8 inches of rainfall at the center of the storm in 4 hours. Discharge at the mouth of Sand Creek was estimated to be 15,000 cfs. Roads and culverts in the storm area were eroded and damaged. Much of the damage along Sand Creek was a result of erosion; there was also damage due to water inundation of homes and businesses.

Within the project area, there are several locations where significant flooding problems have occurred. One example of a significant flooding problem is the I-70/Colorado Boulevard interchange, where ponding depths at the existing drainage structures significantly exceed allowable criteria. Another area where significant flooding occurs is on the elevated portion of I-70 above York Street.

Table 4a of Attachment M—Appendix A: *Drainage Design Criteria Memorandum,* page 10, should read as follows:

Section of Table 4a

Street Grades	Minimum Grade	0.7 Percent (less than 0.5 with variance)		
	Maximum Grade	N/A		

Section 12, References, should read as follows:

12. References

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American Association of State and Highway Transportation Officials. (2002). *Roadside Design Guide*. (3rd ed.). Washington, D.C.: Author.

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National Environmental Policy Act of 1969, Pub. L. No. 91-190, 83 Stat. 852, 42 United States Code § 4321-4327.

RG Consulting Engineers, Inc. (1998). *Final drainage report 56th Avenue Tower Road to Peña Boulevard City and County of Denver*. Denver: Author.

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Wright Water Engineers, Inc. (1990). *Irondale Gulch and District Flow Area 0055 stormwater outfall systems plan*. Denver: Author.

Appendix B has been updated as follows:

Updated reference material is for the MATT reports, which are included in Appendix B. See revised attached Appendix B.

Appendix D has been updated as follows:

The onsite and offsite drainage plan and profile sheets where updated. See revised attached Appendix D.

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Attachment M – Appendix B. Memorandum for I-70 PCL Montclair Drainage Basin Hydrologic Analysis (Update)

Memorandum

To: I-70 PCL Drainage Multi Agency Technical Team (MATT)
- Urban Drainage and Flood Control District (UDFCD)
- Colorado Department of Transportation (CDOT)
- City and County of Denver (CCD)
- Regional Transportation District (RTD)
- Atkins
- Stantec

From: Don Jacobs P.E. – Enginuity Engineering Solutions (Enginuity)

Date: August 1, 2014

Re: I-70 PCL **Montclair** Drainage Basin Hydrologic Analysis

1.0 Contents of this Memorandum

This memorandum was prepared by Enginuity Engineering Solutions documenting the Multi Agency Technical Team's (MATT) investigation of the Montclair drainage basin hydrology in Denver, Colorado. A list of individual MATT participating members is located in the appendix (see meeting minutes) and includes the Urban Drainage and Flood Control District (UDFCD), the Colorado Department of Transportation (CDOT), the City and County of Denver (CCD), and the Regional Transportation District (RTD). Organizational contents of this memorandum are listed below:

2.0 Background and Purpose

CDOT has identified the Partial Covered Lowered Alternative (PCL) as the preferred alternative for improvements to I-70 East through Denver. A portion of this alternative includes rebuilding I-70 below grade between Brighton Boulevard and Colorado Boulevard, where the existing viaduct currently stands. While lowering the highway at this location provides several enhancements to the community such as reconnecting the Elyria and Swansea neighborhoods, it also presents drainage challenges that must be addressed from a design standpoint.

The proposed lowered portion of the I-70 project crosses two major drainage basins in Denver – the Montclair and Park Hill basins. This memorandum specifically addresses the Montclair basin. Flood

potential in the lower Montclair drainage basin has been documented by several previous studies, including studies by the City and County of Denver and the Regional Transportation District. These studies have defined flow rates and rough flooding limits around the I-70 area both upstream and downstream of the interstate. Currently, this flood potential does not pose a significant risk to the highway due to its elevated design on a viaduct. However, proposed lowering of alignment below grade will introduce the potential for flood waters to enter the highway if not accounted for in the project's drainage design.

To address this potential drainage issue, the MATT was formed during the fall of 2013 to collectively investigate the Montclair basin's hydrology and other inter-agency coordination issues. While the Montclair basin hydrology has been documented in several previous studies (see below for more information), all of the previous analyses were performed from a regional planning standpoint, and there was a general presumption that the previously published flow rates could potentially be overly conservative from a design standpoint. Specific factors such as conservative impervious values, existing inadvertent detention that may exist within the basin, CUHP model discretization, and limited accounting for floodplain flow routing were to be investigated.

Overall goal of this analysis: to perform a technical review of the previous Montclair basin hydrologic analysis and modify the modeling, if necessary, in order to provide C-DOT with a mutually agreed upon off-site 100-year design flow rate for the I-70 PCL project.

Previous analysis that were used as the initial basis of this project:

- 2005 CCD Storm Drainage Master Plan (SDMP)
- 2008 CCD Ferril Lake Stormwater Detention Design
- 2009 CCD Storm Drainage Master Plan
- 2010 CCD Sanitary and Storm Drainage Master Plan FasTracks Interface
- 2014 CCD Storm Drainage Master Plan (in progress, scheduled for completion in October 2014)
- 2008 RTD Draft East Corridor Drainage Master Plan
- 2011 RTD Eagle P3 Drainage Adverse Impact Analysis
- 2013 RTD North Metro FLO-2D Drainage Analysis
- 2011-2014 RTD/CCD/UDFCD 40th Avenue/High Street Outfall Design
- 2012 UDFCD Park Hill (North of Smith Road) Drainage Outfall Systems Plan

This memorandum documents the hydrologic analysis performed by Enginuity in the Montclair basin for the I-70 PCL project's conceptual design. The analysis was a collaborative effort between MATT members with bi-weekly technical meetings held from September 2013 thru February 2014. Hydrology related meeting minutes are included in the appendix.

3.0 General Approach – Base Model Hydrology

General Hydrologic Conditions

The Montclair basin is a fully developed, urbanized watershed containing a total tributary drainage area of approximately 9.4 square miles. It encompasses drainage planning basins 4500-01, -03, and -04. The basin generally drains to the northwest and discharges to the South Platte River between Globeville Landing Park and Riverside Cemetery. Its upstream boundary is located to the southeast at the Fairmont Cemetery. Land use varies within the basin from primarily residential in the upper reaches to commercial and industrial in the lower reaches. City Park, an approximate 320 acre urban park containing the Denver Zoological Gardens, the Denver Museum of Nature & Science, and the City Park Golf Course, is located near the center of the drainage basin.

There is an extensive system of existing storm sewer pipes serving the basin including a 10' x 10' RCBC primary outfall. A second large (12' x 8' RCBC) outfall associated with the RTD Eagle P3 project in conjunction with UDFCD and CCD is currently under construction. These two outfalls combined were designed to convey the 5-year event. Surcharged flows in excess of the storm sewers' capacity are conveyed overland via the network of City streets. There is historical evidence that a drainage channel once existed in the Montclair basin, but it has since been obliterated by development during the early 20th century. Without a formal drainage channel, periodic flooding occurs throughout the basin with significant surface runoff. These areas of urban flooding are not recognized by FEMA as jurisdictional floodplains, but they pose a significant drainage design issue for the I-70 PCL project as they drain towards the highway.

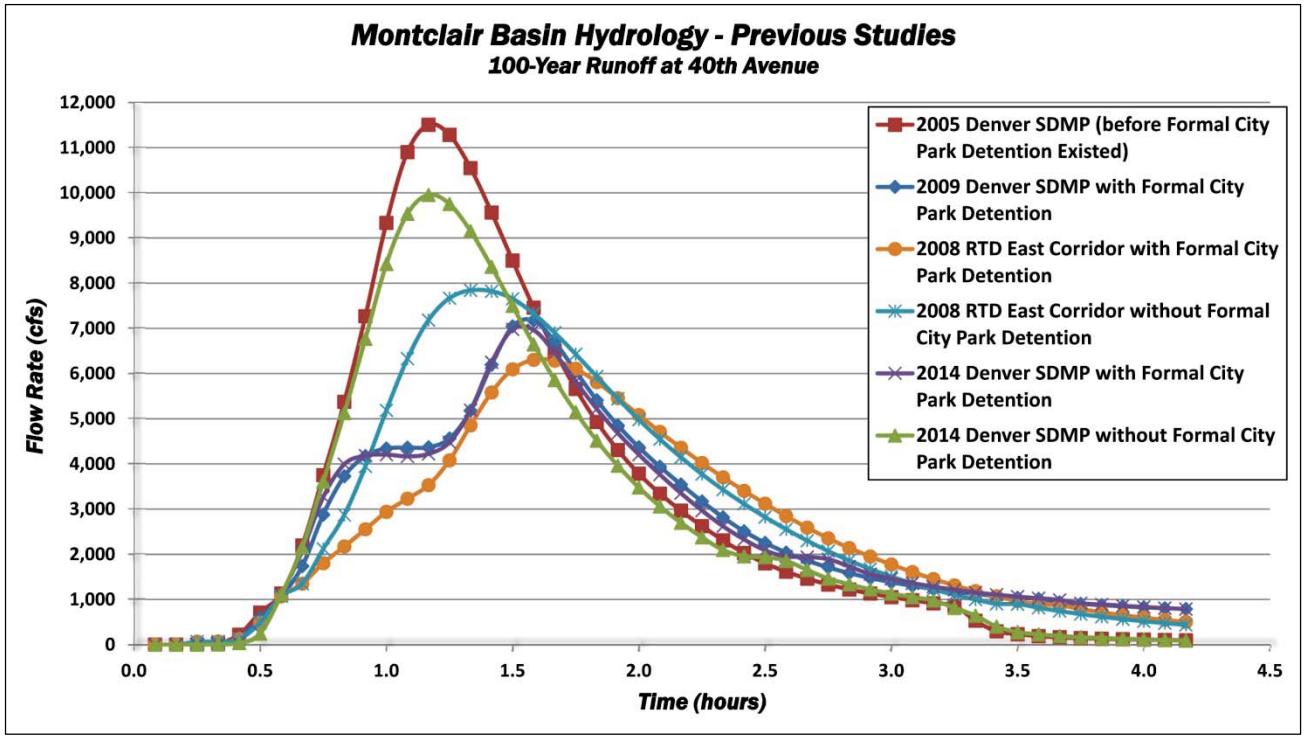
Previous Studies and Flow Rates

With numerous previous studies encompassing different portions of the Montclair drainage basin for a variety of purposes, the MATT began by investigating hydrologic results and flow rates published in the previous studies. In order to adequately compare these studies, Enginuity modified the previous CUHP/SWMM models as necessary to provide comparative results at a common location using identical assumptions. For the purpose of consistency when comparing previous studies, the following assumptions were used:

- The location for comparing flow rates produced by the Montclair basin is at 40th Avenue and represents a combined flow rate across several streets and pipes. **All comparative flow rates published in this memorandum are at 40th Avenue** and are represented as "Design Point 2" in the modeling. Once water crosses 40th Avenue, it branches into several different directions and is conveyed by various underground pipes and multiple streets. These diversions downstream (north) of 40th Avenue are accounted for in the accompanying *I-70 PCL MATT Park Hill Basin Hydrology* technical memorandum.

- **Comparative Flow rates throughout this study represent the total 100-year runoff from the basin (pipe flow plus surface flow).** For the sake of simplicity, underground pipe conveyances are not separated from the surface flow conveyances in the comparative flow rate analysis in this memorandum (DP 2). More detailed separated pipe and surface flow rates can be obtained from the updated SWMM modeling in this memorandum, but they are not used for the comparative analysis herein. These pipe conveyances should be accounted for as part of the future I-70 conceptual design.

Considering the assumptions listed above, runoff hydrographs from previous studies are depicted in the graph below:



The "City Park Detention" referenced in the graph above refers to formalized detention constructed in 2008 at Ferril Lake, which consists of approximately 124 acre-feet of detention volume and was designed for the 5-year event. While not all of the previous studies originally analyzed the basin with and without formalized detention at Ferril Lake, Enginuity added this variation to the previous models for comparative purposes and to provide the MATT with a clear understanding of the expected benefits of the existing 5-year Ferril Lake facility.

General background of the previous studies (all utilize CUHP 2000 and UDSWMM 2000):

- 2005 Denver SDMP: the first major study of the basin; utilized detailed CCD topography and GIS data; basin delineation based on pipe infrastructure; estimated % impervious values based on UDFCD land use table; delineated 57 individual sub-basins.

- 2008 RTD East Corridor: more "basic" analysis delineating 5 individual sub-basins; basin delineation based on topography; estimated % impervious values based on UDFCD land use table.

- 2009 Denver SDMP: modified 2005 model to account for City Park detention; revised % impervious calculations to be based on measured impervious values for each land use utilizing the City's GIS pervious layer; other minor modeling parameter modifications.

- 2014 Denver SDMP: modified 2009 model's routing and basin delineations to account for various surface split-flows identified using FLO-2D; routing elements account for both pipe and surface flow splits instead of pipe only; other minor modifications to account for newly constructed projects.

See the original technical documentation for each of these studies for additional information, maps, and results.

Determination of Base Hydrologic Model

The MATT reviewed results from previous modeling and decided to move forward with the 2014 Denver SDMP CUHP/UDSWMM analysis as the "Base Model" for the I-70 PCL analysis. This model was selected due to the fact that it is the latest model available, incorporates both surface and pipe flow routing, and provides a significant level of additional detail over the RTD analysis. A CUHP-UDSWMM routing schematic map representing this model is located in the appendix, which includes a summary of 100-year peak flow rates for each design point. The model has been modified by Enginuity for the purposes of this study, by combining several design points into a single point at 40th Avenue to represent the total flow for the basin. The total flow is represented by Design Point "2" in the revised model, with a 100-year peak flow rate of 6,979 cfs.

The base model was then utilized to perform a series of sensitivity analyses accounting for potential modifications to modeling parameters that the group had identified as potentially more accurate, and also accounting for physical features observed within the basin that were not previously accounted for in the model. The results of this sensitivity analysis are discussed in the following section.

4.0 Hydrologic Modeling Sensitivity Analysis

The MATT investigated the following potential modifications to the base CUHP/UDSWMM modeling and performed a sensitivity analysis on each:

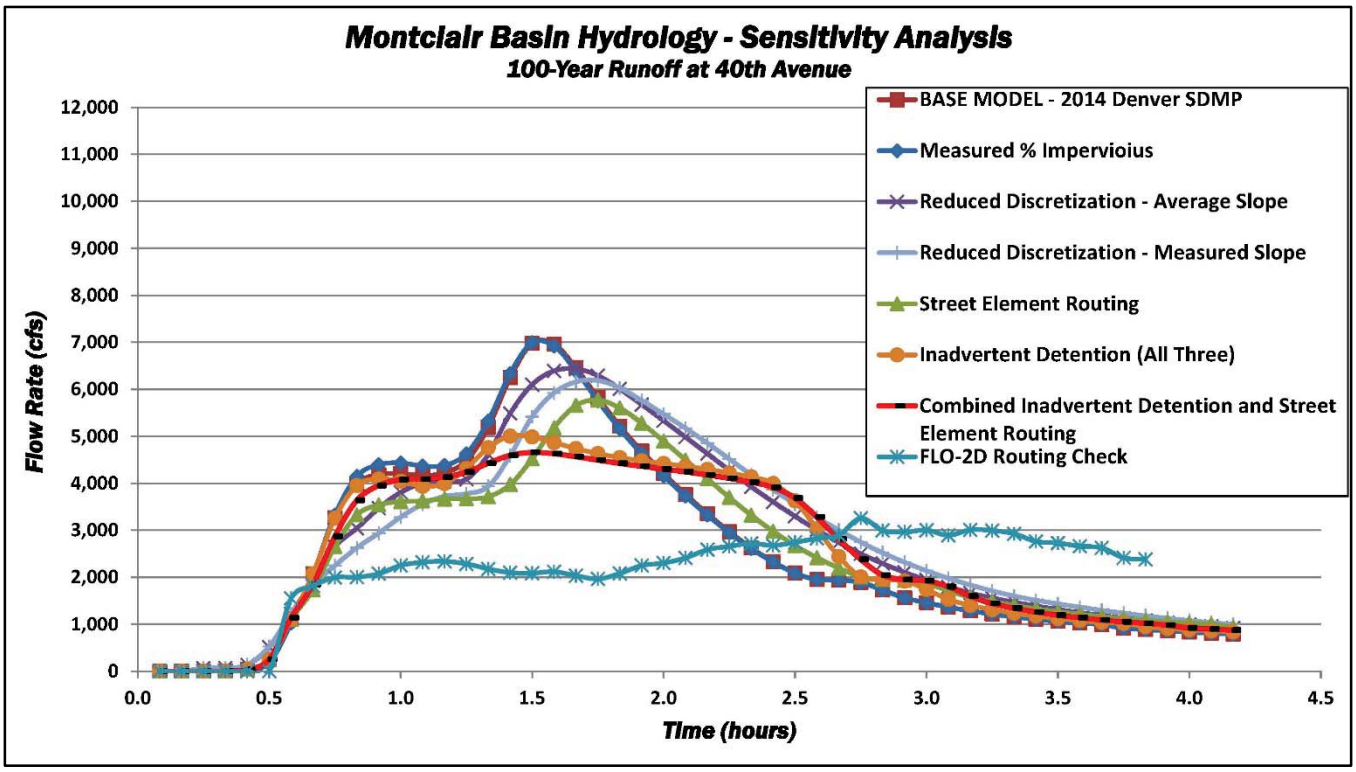
1. Accounting for **loss of surface runoff to the 36th Street** drainage basin.
2. Utilizing direct **measured impervious values** instead of land use based values.
3. Reducing the model's **discretization** by subdividing the basin into fewer sub-basins.
4. Modifying the **street routing elements** in UDSWMM to better represent flow occurring down multiple streets during the 100-year event.
5. Accounting for **inadvertent detention** that occurs within the basin.

The following table and graph summarize peak runoff rates and hydrographs for the various modeling modifications investigated by the MATT. The subsequent subsections further discuss the sensitivity analysis performed for each potential modification.

Montclair Basin Hydrology – Sensitivity Analysis
100-Year Runoff at 40th Avenue

Model or Potential Modification*	Q100 (cfs)	Change from Base Model	Comment
2014 CCD Master Plan	**6979**	0%	**Base Model, CUHP 2000, UDSWMM 2000**
Loss of surface runoff to 36th Street Basin	6598	-5%	Straight subtraction of peak flow acquired from FLO-2D model
Measured % Impervioius	6991	0.2%	1% increase in total % Impervious
Reduced Discretization - Weighted Average Slope	6432	-8%	59 sub-basins to 5 sub-basins
Reduced Discretization - Measured Basin Slope	6188	-11%	59 sub-basins to 5 sub-basins
Multiple Street X-section Routing Elements	5793	-17%	Adjusted trapazoidal bottom width and side slopes
Inadvertent Detention in City Park below Ferril Lake	5644	-19%	45.5 acre-feet assumed Inadvertent Detention
Inadvertent Detention in City Park Golf Course	5619	-19%	41.8 acre-feet assumed Inadvertent Detention
Inadvertent Detention in City Park Ball Fields	6825	-2%	18.2 acre-feet assumed Inadvertent Detention
Inadvertent Detention - all 3 combined	5005	-28%	105.5 acre-feet assumed Inadvertent Detention (total)
Check: FLO-2D Routing for Basin Below Colfax Avenue	3255	-53%	Accounts for all inadvertent detention throughout the lower basin. Includes pipe flow. Includes flow lost to 36th Street. **Low-end check only.**
Modification Combinations			
Multiple Street X-section Routing Elements & Inadvertent Detention (all 3 locations)	4422	-37%	Combination requested by MATT on 12/16/2013
Multiple Street X-section Routing Elements & Inadvertent Detention (Golf Course and Duck Pond only)	4655	-33%	Combination requested by Matt on 2/19/2014 and adopted in agreement with Denver Parks Department

* All models represent total peak runoff produced by the basin, existing pipe outfalls are not considered. All models account for existing detention at City Park in Ferril Lake and also Crestmore Park.
Red = changes recommended by MATT



4.1. Loss of Water to 36th Street Basin

FLO-2D analysis performed in the 2014 Denver SDMP indicated that there is potential for some flood waters to exit the Montclair basin and enter the 36th Street basin during large storm events. The location for this potential trans-basin flow to the west would occur across Lafayette Street in the lower portion of the basin between 31st Avenue and 36th Avenue. See the Montclair-Park Hill Basin Depth map in the appendix for a depiction of this trans-basin flow location.

As part of the MATT analysis, modifications to the 2014 SDMP FLO-2D analysis were made in order to track the trans-basin flow into the 36th Street basin. The modeling results produced a trans-basin flow of 381 cfs from Montclair to 36th Street during the 100-year event. The MATT determined this amount of flow loss to be negligible and decided not to account for it in the Montclair basin hydrology.

4.2. Measured Impervious Values

As part of the MATT analysis, the impervious values for each sub-basin were directly measured utilizing CCD's impervious layer in GIS. While the exact measured values differed from the 2014 SDMP base model for individual sub-basins, the cumulative basin-wide percent impervious value only differed by 1% and produced a negligible change in runoff values. Based on this result, the MATT decided not to modify the base model's impervious values.

4.3. Reduced Discretization

It is generally understood that the more a large basin is subdivided for CUHP/SWMM analysis (discretized), higher resulting flow rates can be expected. Often times during CUHP/SWMM model development, engineers will model a basin utilizing different levels of discretization, and compare the results in order to "calibrate" the model based on the original basis of development for CUHP itself.

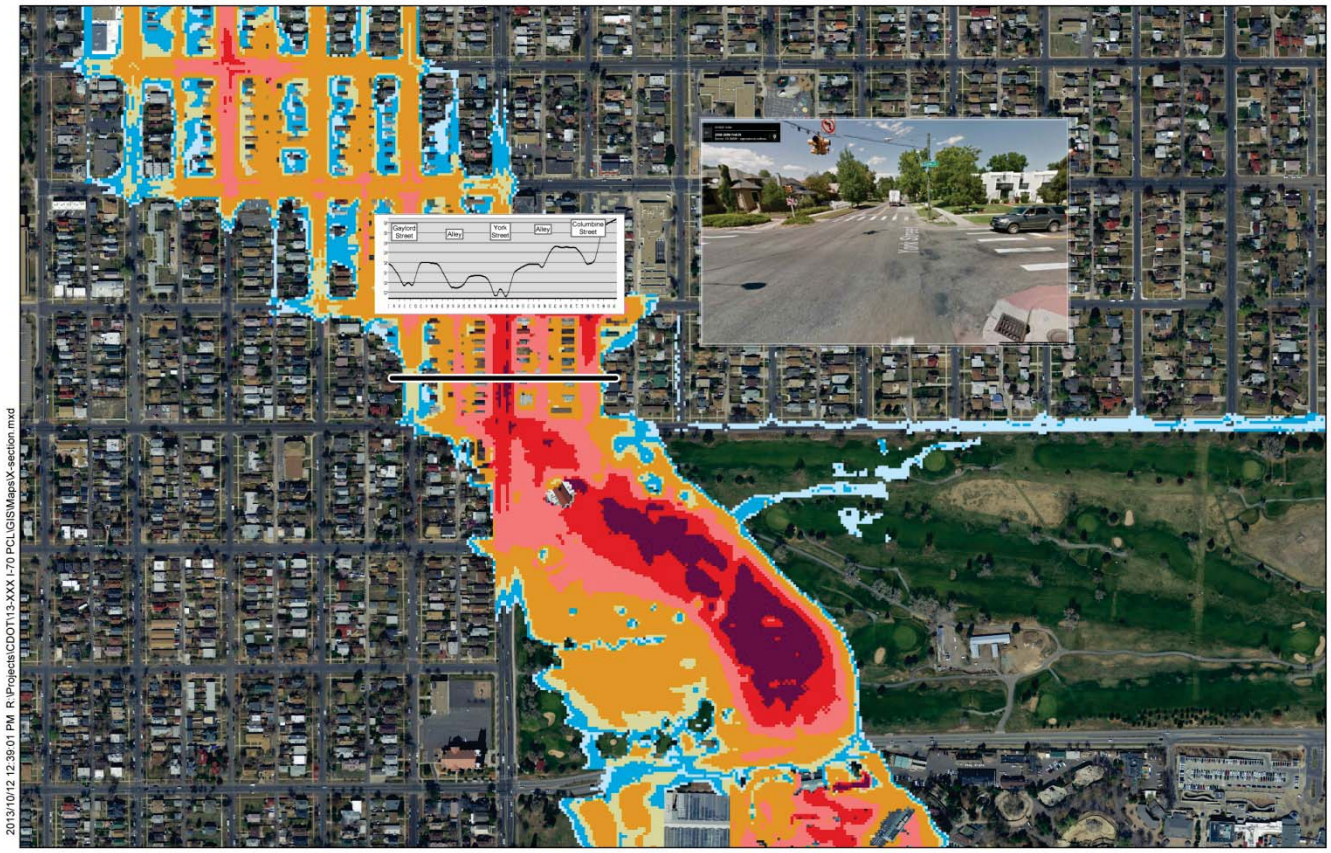
The MATT checked the sensitivity of the Montclair model by reducing the discretization from 59 sub-basins in the base 2014 SDMP model to a 5 sub-basin model. The result was an 8% to 11% decrease in peak flow rates at 40th Avenue depending on the method used to calculate sub-basin slopes. The MATT determined that this difference between the two approaches was acceptable, and did not warrant

modification to the base model. The MATT decided to continue with the more conservative, 59 sub-basin approach in the 2014 SDMP without further modification to account for discretization.

4.4. Multiple Street SWMM Routing Elements.

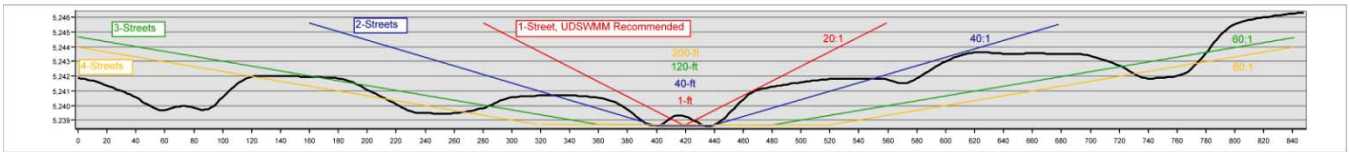
The street routing elements in the 2014 SDMP base UDSWMM model were input as recommended in the UDSWMM User's Manual. The recommended cross section is a 1-foot bottom width trapezoidal section, with 20:1 side slopes. The UDSWMM model can only accept trapezoidal shaped cross sections to represent surface flow. This standard cross section is intended to represent a street's gutter section, and can be thought of as an "inverted street crown." While this recommended cross section provides a good representation for water flowing down a single street, portions of the Montclair basin experience widespread flooding with water flowing down multiple streets, alleys, and around structures. In order to better represent the nature of this 100-year flood routing, the MATT developed several wider cross sections to be utilized in the SWMM model depending on the nature of the street flow at individual locations. The nature of the street flow was determined using FLO-2D surface modeling results from the 2014 SDMP.

A representative section located just north of 26th Avenue across the basin's primary flow path was utilized to depict the nature of street flow through the basin during the 100-year event. The following figure shows the typical nature of flow and a typical cross section within the basin, a larger version of this image is available in the appendix:



The following figure illustrates four different routing cross sections used in the MATT UDSWMM analysis representing a varying number of streets conveying the runoff. The typical ground cross section north of 26th Avenue is shown in the background in black. A larger version of this image is available in the appendix.

- Flow traveling down one street (UDSWMM User's Manual recommendation) in red. 1-foot bottom width, 20:1 side slopes.
- Flow traveling down two streets in blue. 40-foot bottom width, 40:1 side slopes.
- Flow traveling down three streets in green. 120-foot bottom width, 60:1 side slopes.
- Flow traveling down four+ streets in yellow. 200-foot bottom width, 60:1 side slopes.



When comparing these cross sections to actual ground cross sections where flow occurs down multiple streets, the MATT believes these routing element representations are conservative, with actual flooding being realistically wider, slower, and more shallow than the trapezoidal sections used in the UDSWMM model.

Several velocity checks were completed to ensure the revised trapezoidal x-section routing elements are still considered to be conservative. Results indicate that velocities calculated in SWMM for a representative trapezoidal routing element are in fact higher (more conservative) than other methods of determining flow velocities in the area. Velocity calculations performed for comparison purposes are listed below:

Velocity Check for 6000 cfs, 0.05 ft/ft longitudnal slope, 0.02 Manning's n

Manning's Velocity for Irregular Section (3-Streets):	6.8 fps
Manning's Velocity for Trapezoidal Section:	7.6 fps
EPASWMM Velocity for Irregular Section (3-Streets):	7.4 fps
EPASWMM Velocity for Trapezoidal Section:	7.8 fps (used in revised modeling)
FLO-2D Computed Velocity:	3 to 7 fps

Revision of the UDSWMM street flow routing elements resulted in a 17% decrease in peak flow rates from the base model. The MATT recommended incorporating these revisions into the I-70 hydrology to better represent 100-year flow conditions within the basin. See the UDSWMM routing map in the appendix for specific locations where the routing elements were modified to better represent street flow conditions.

4.5. Inadvertent Detention

Three areas of significant inadvertent detention were identified within the basin that could have a significant impact on peak flow rates aimed at the I-70 project. Inadvertent detention is referred to as naturally occurring detention storage that exists within low-lying and depressed areas; these areas have not been designed, constructed, or maintained for the purposes of stormwater detention. Inadvertent detention is not typically accounted for in design hydrology due to the fact it cannot be relied upon for future storage of flood waters. As a general practice, it is typically assumed that areas of inadvertent storage could be modified in the future resulting in a reduction or elimination of the storage that currently occurs. However, the three areas identified in the Montclair basin are located on CCD publically owned property, where assurances can potentially be provided to maintain the existing inadvertent detention storage volumes in perpetuity.

The MATT investigated inadvertent volumes and the impact they have on the basin's hydrology at the following locations:

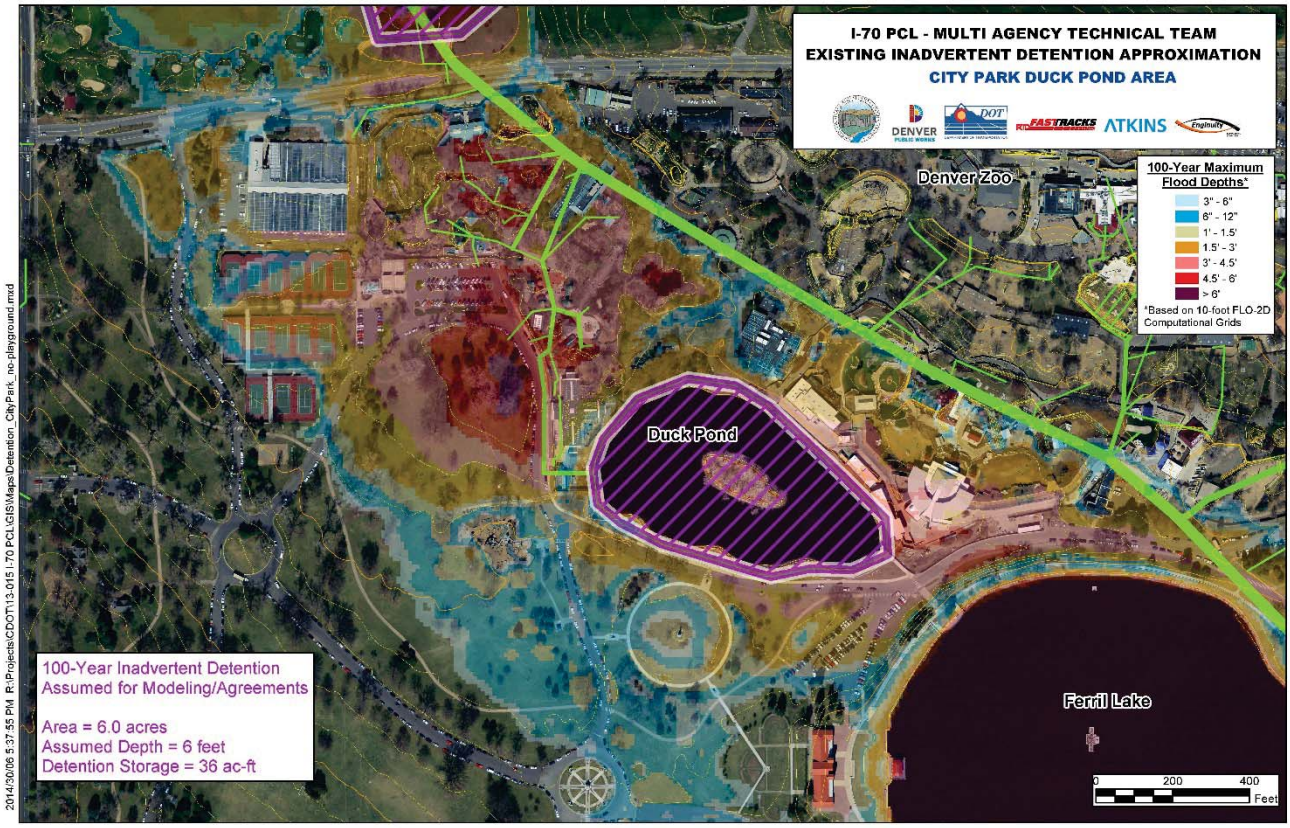
1. City Park below (north of) Ferril Lake (Duck Pond area). Assume 45.5 acre-feet including the playground area, or 36.0 acre-feet without the playground area.

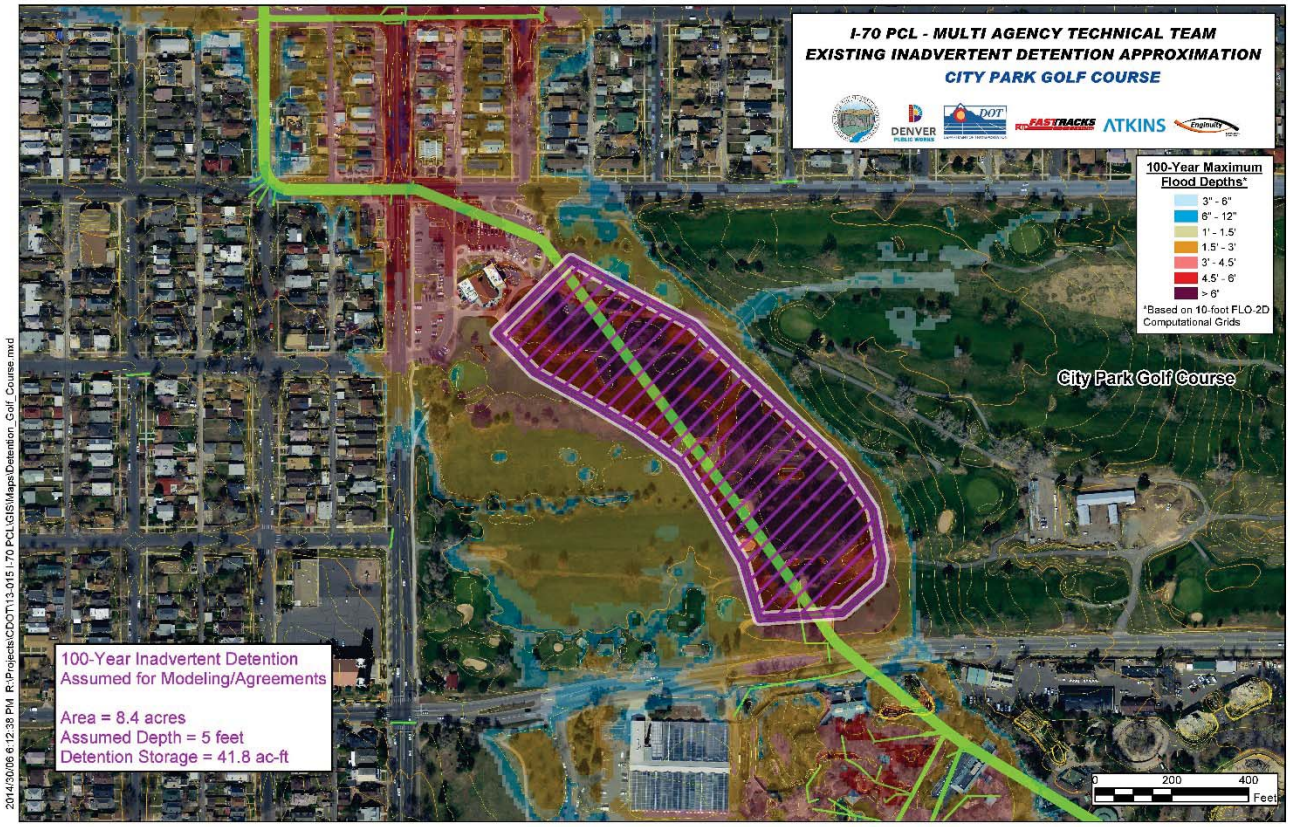
2. City Park Golf Course between 23rd and 26th Avenues. Assume 41.8 acre-feet.

3. City Park Ball Fields west of Colorado Boulevard and south of 23rd Avenue. Assume 18.2 acre-feet.

See the appendix for mapping of these three areas and assumed inadvertent detention volume calculations. These inadvertent detention volumes are considered by the MATT to be conservative, with actual 100-year inadvertent detention volumes being significantly larger than the assumed values.

The addition of these inadvertent detention volumes into the UDSWMM model results in significantly reduced flow rates at 40th Avenue. If all three areas are accounted for, a 28% reduction in 100-year peak flow rates is realized. See the table at the beginning of this section for specific results from each individual area. After coordination with the Denver Parks Department, the MATT recommended accounting for two of the three inadvertent detention areas in the I-70 hydrology. A legal agreement has been finalized with the Denver Parks Department assuring future actions will not adversely impact the natural and formal storage currently occurring at these two locations. The two locations where inadvertent detention has been accounted for in both the modeling and the agreement with the Parks Department includes the Duck Pond area of City Park and the City Park Golf Course. Both areas are depicted in the figures below:





4.6. FLO-2D Routing

As a "low end check" of the overall hydrologic results for the basin, runoff values from the 2014 SDMP FLO-2D model were included in the sensitivity analysis documentation. The routing of flood conveyances utilizing FLO-2D is not a methodology approved by UDFCD because it accounts for every square foot of inadvertent detention within the basin, and it is generally considered to lack enough conservatism when determining peak flow rates for design purposes. However, the FLO-2D results have been included in the sensitivity analysis tables and graphs as a simple reference point, allowing the MATT to further understand the various modeling results and help make final modeling recommendations.

4.7. Technical Peer Review of Analysis

UDFCD contracted with an independent 3rd party, CH2M Hill, to conduct a peer review of the sensitivity analysis and a general review of the CUHP/SWMM modeling for the Montclair Basin. The review was completed on May 9, 2014 and the results are provided in the Appendix. The review did not recommend any significant changes to the modeling approach or analysis.

5.0 Revised I-70 PCL Hydrology Results and Final MATT Recommendations

Recommendations

After reviewing the previous hydrologic studies performed for the Montclair drainage basin and further performing a sensitivity analysis of various modeling parameter modifications, the MATT has recommended the following modifications be made to the base 2014 SDMP CUHP/SWMM model for I-70 design purposes:

- Revise UDSWMM routing elements to more accurately represent flow occurring down multiple streets.

- Account for inadvertent detention at the following two locations: City Park Duck Pond (36.0 acre-feet), and City Park Golf Course (41.8 acre-feet). The Inadvertent Detention Memorandum of Understanding (MOU) between CCD Public Works and Denver Parks and Recreation has been finalized ensuring future maintenance of the flood storage volumes.

Results

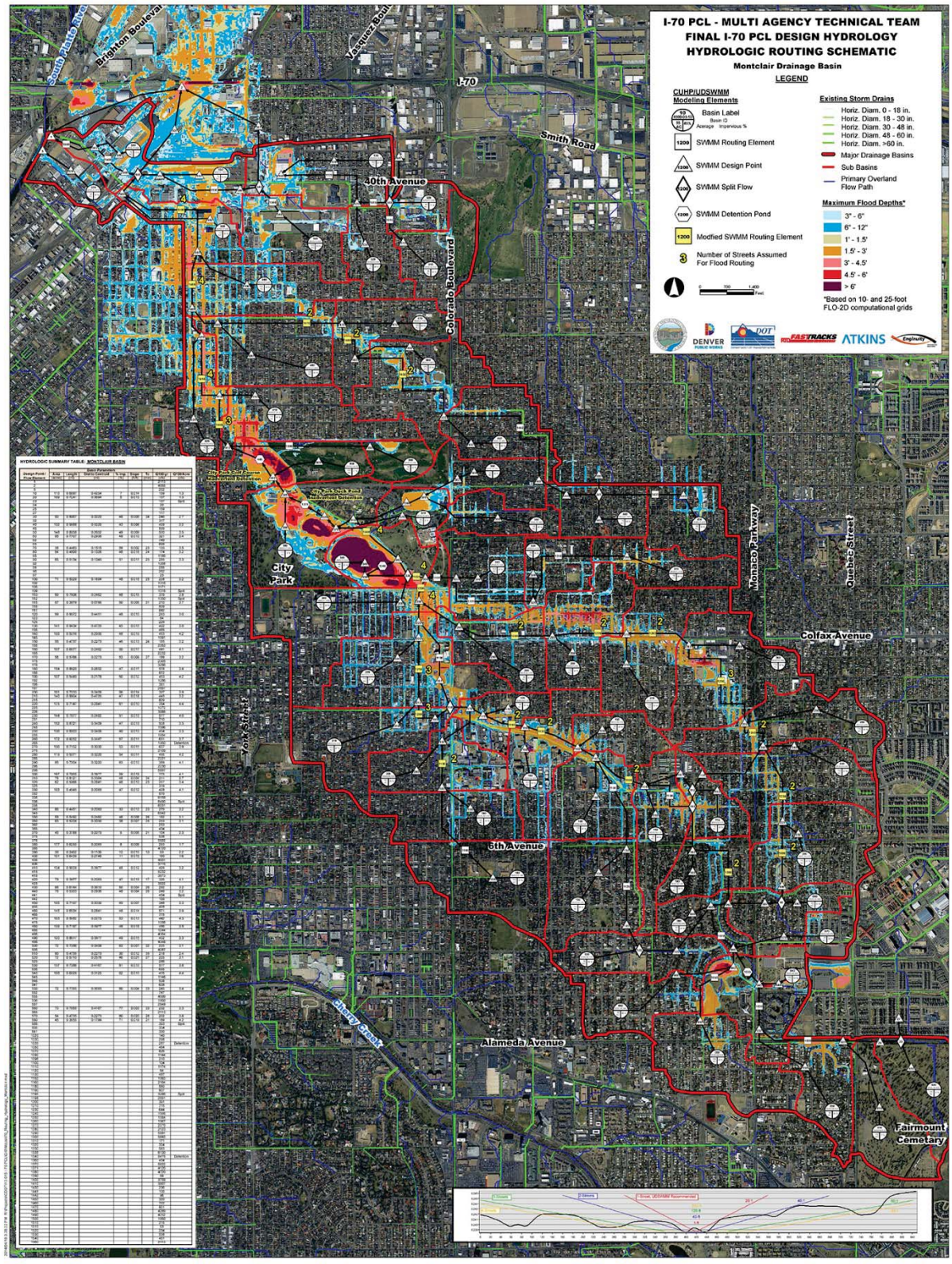
Incorporating the MATT recommendations into the CUHP/SWMM hydrologic modeling, a revised total basin 100-year peak flow rate of 4,655 cfs is calculated at 40th Avenue. From this value, the I-70 design team can account for existing and soon-to-be completed pipe outfalls serving the basin by subtracting their capacities from the total peak flow rate. Based on CCD's GIS data and recent construction plans, the following two main outfalls should be accounted for:

- Existing 120" BRICK @ 0.39% serving 40th Street and 40th Avenue with a calculated Manning's full flow capacity of 897 cfs.

- Currently under construction High Street Outfall (UDFCD, Denver, RTD) serving 40th Avenue and the East Corridor rail alignment with a design capacity of 906 cfs (based on construction plans dated January 2013). The latest construction plans or as-builts for this project should be referenced to verify this number.

Accounting for the two storm drain outfalls serving the Montclair basin, the 100-year design flow rate at 40th Avenue (surface flow) is 2,852 cfs (4,655 minus 897 minus 906). This peak flow rate can be further revised during the design process to account for the complex flood routing and split flows that occur between 40th Avenue and I-70.

This flood routing between 40th Avenue and I-70 has already been preliminarily completed for the RTD North Metro project and was incorporated into the 2014 SDMP Base modeling for the Montclair and Park Hill Basins. The revised MATT CUHP/SWMM Park Hill basin model includes the storm drain outfalls listed above and combines flows from both the Montclair and Park Hill basins in the vicinity of I-70. **Please refer to the accompanying *I-70 PCL MATT Park Hill Basin Hydrology* technical memorandum for a more detailed determination of peak flow rates anticipated at I-70.**



This image represents the Montclair basin's SWMM Routing diagram, a larger version is available in the appendix.

6.0 Appendix

All supporting maps, figures, tables, and hydrologic models used during the MATT analysis are provided in electronic format only. All supporting documentation can be found on the attached DVD.

The supporting documents are organized in the same general order to match the layout of this memorandum. Supporting documents include:

01. Figures/Maps/Tables:

- A. Background Montclair Mapping
    - i. Montclair/Park Hill Basin FLO-2D Flooding Depth Analysis
    - ii. 2011-07-07 Flooding Video at 36th Avenue and High Street
    - iii. 2008 RTD East Corridor CUHP-SWMM Routing Diagram
    - iv. 2014 SDMP Base Model CUHP-SWMM Routing Diagram
- B. Hydrology Sensitivity Analysis
    - i. Impervious Value Sensitivity Analysis
    - ii. Reduced Discretization Sensitivity Analysis
    - iii. Multiple Street SWMM Routing
    - iv. Inadvertent Detention
- C. Final Hydrologic Mapping for I-70 PCL
    - i. Final MATT I-70 PCL CUHP-SWMM Routing Diagram

02. Hydrologic Models CUHP-UDSWMM:

- A. Previous Models Modified by Enginuity for Comparative Purposes
    - i. 2008 RTD East Corridor (with and without Ferril Detention)
    - ii. 2014 Denver SDMP with Ferril Detention
    - iii. 2014 Denver SDMP without Ferril Detention
- B. Sensitivity Analysis
    - i. Base 2014 Denver SDMP
    - ii. Measured Imperviousness
    - iii. Reduced Discretization
    - iv. Multiple Street X-section Routing
    - v.a. Inadvertent Detention City Park Duck Pond

- v.b. Inadvertent Detention City Park Golf Course
- v.c. Inadvertent Detention City Park Ball Fields
- v.d. Inadvertent Detention Combined (all 3)

- C. Final Hydrology Revised for I-70 PCL
  - i. Combined Inadvertent Detention and Multiple Street Routing

03. Peer Review of Analysis

04. MATT Meeting Minutes

Memorandum

To: I-70 PCL Drainage Multi Agency Technical Team (MATT)
- Urban Drainage and Flood Control District (UDFCD)
- Colorado Department of Transportation (CDOT)
- City and County of Denver (CCD)
- Regional Transportation District (RTD)
- Atkins
- Stantec

From: Don Jacobs P.E. – Enginuity Engineering Solutions (Enginuity)

Date: August 1, 2014

Re: I-70 PCL **Park Hill** Drainage Basin Hydrologic Analysis

1.0 Contents of this Memorandum

This memorandum was prepared by Enginuity Engineering Solutions documenting the Multi Agency Technical Team's (MATT) investigation of the Park Hill drainage basin hydrology in Denver, Colorado. A list of individual MATT participating members is located in the appendix (see meeting minutes) and includes the Urban Drainage and Flood Control District (UDFCD), the Colorado Department of Transportation (CDOT), the City and County of Denver (CCD), and the Regional Transportation District (RTD). Organizational contents of this memorandum are listed below:

2.0 Background and Purpose

CDOT has identified the Partial Covered Lowered Alternative (PCL) as the preferred alternative for improvements to I-70 East through Denver. A portion of this alternative includes rebuilding I-70 below grade between Brighton Boulevard and Colorado Boulevard, where the existing viaduct currently stands. While lowering the highway at this location provides several enhancements to the community such as reconnecting the Elyria and Swansea neighborhoods, it also presents drainage challenges that must be addressed from a design standpoint.

The proposed lowered portion of the I-70 project crosses two major drainage basins in Denver – the Montclair and Park Hill basins. This memorandum specifically addresses the Park Hill basin. Flood potential

in the lower Park Hill drainage basin has been documented by several previous studies, including studies by the City and County of Denver, UDFCD, and the Regional Transportation District. These studies have defined flow rates and rough flooding limits around the I-70 area both upstream and downstream of the interstate. Currently, some of the identified flood potential in the Park Hill basin does not pose a significant risk to the highway due to its elevated design on a viaduct, except for an area just east of Colorado Boulevard, where I-70 is currently at-grade. However, proposed future lowering of alignment below grade will introduce the potential for flood waters from the Park Hill basin to enter the highway if not accounted for in the project's drainage design.

To address this potential drainage issue, the MATT was formed during the fall of 2013 to collectively investigate the Park Hill basin's hydrology and other inter-agency coordination issues. While the Park Hill basin hydrology has been documented in several previous studies (see below for more information), all of the previous analyses were performed from a regional planning standpoint, and there was a general presumption that the previously published flow rates could potentially be overly conservative from a design standpoint. Specific factors such as conservative impervious values, existing inadvertent detention that may exist within the basin, CUHP model discretization, and limited accounting for floodplain flow routing were to be investigated.

Overall goal of this analysis: to perform a technical review of the previous Park Hill basin hydrologic analysis and modify the modeling, if necessary, in order to provide C-DOT with a mutually agreed upon off-site 100-year design flow rate for the I-70 PCL project.

Previous analysis that were used as the initial basis of this project:

- 2005 CCD Storm Drainage Master Plan (SDMP)
- 2009 CCD Storm Drainage Master Plan
- 2010 CCD Sanitary and Storm Drainage Master Plan FasTracks Interface
- 2011 CCD Sand Creek and Upper Park Hill Basins Final Drainage Study
- 2012 UDFCD Park Hill (North of Smith Road) Drainage Outfall Systems Plan
- 2014 CCD Storm Drainage Master Plan (in progress, scheduled for completion in October 2014)
- 2008 RTD Draft East Corridor Drainage Master Plan
- 2011 RTD Eagle P3 Drainage Adverse Impact Analysis

This memorandum documents the hydrologic analysis performed by Enginuity in the Park Hill basin for the I-70 PCL project's conceptual design. The analysis was a collaborative effort between MATT members with bi-weekly technical meetings held from September 2013 thru February 2014. Hydrology related meeting minutes are included in the appendix.

3.0 General Approach – Base Model Hydrology

General Hydrologic Conditions

The Park Hill watershed encompasses a total area of approximately 5.75 square miles near its outfall at the South Platte River. Flow from the basin generally travels from south to north and enters the South Platte River approximately 2,500 feet downstream of Brighton Boulevard, east of York Street. The majority of the watershed is located within the City and County of Denver and is fully developed. Topography within the basin is generally mild with grades ranging from 0.5% to 2%.

During larger storm events, runoff is conveyed through the basin primarily by the streets as surface flow, with several storm drain pipes also conveying water to the north. Most of the basin lacks a formal drainageway, or even a low lying area, to convey water. Throughout the basin, there are numerous surface features such as railroad embankments, local roadways, major highways, and underpasses, that split surface runoff in at least two directions. These surface flow "splits" combined with several storm drainage pipes conveying water in various directions creates a relatively complex drainage basin with sometimes difficult to determine primary flowpaths.

Previous Studies and Flow Rates

With numerous previous studies encompassing different portions of the Park Hill drainage basin for a variety of purposes, the MATT began by investigating hydrologic results and flow rates published in the previous studies.

General background of the previous studies:

- 2005 Denver SDMP: the first major study of the basin (CUHP 2000 and UDSWMM 2000); utilized detailed CCD topography and GIS data; basin delineation based on pipe infrastructure; estimated % impervious values based on UDFCD land use table; delineated 25 individual sub-basins above I-70 spanning Denver basins 0060-02, 0060-01 and 4400-02.

- 2008 RTD East Corridor: more "basic" analysis delineating 18 individual sub-basins and only extending down to Smith Road; basin delineation based on topography; estimated % impervious values based on UDFCD land use table. Utilized CUHP 2000 & UDSWMM 2000.

- 2009 Denver SDMP: modified 2005 model to account for 38th & Holly detention; revised % impervious calculations to be based on measured impervious values for each land use utilizing the City's GIS pervious layer; other minor modeling parameter modifications. Utilized CUHP 2000 and UDSWMM 2000.

- 2011 CCD Sand Creek and Upper Park Hill Basins Final Drainage Study: refined the SDMP analysis and incorporated FLO-2D modeling in the upper basin to develop several pipe conveyance alternatives south of Smith Road. Updated modeling to CUHP 2005 and EPASWMM 5.

- 2012 UDFCD Park Hill (North of Smith Road) Drainage Outfall Systems Plan: studied the lower portion of the basin near the outfall to the South Plate River and developed design alternatives to eliminate flooding north of Brighton Boulevard. Additional FLO-2D modeling was developed for the lower basin north of Smith Road to determine primary flow paths and estimate flood routing parameters. Updated modeling to CUHP 2005 and EPASWMM 5.

- 2014 Denver SDMP: combined modeling and documented results from the previous studies listed above – 2009 SDMP, 2011 Sand Creek, and 2012 OSP. Also linked results from the neighboring Montclair Basin, where trans-basin flows occur between the two basins. Modeling included a mix of both CUHP 2000 and UDSWMM 2000 as well as CUHP 2005 and EPASWMM 5 depending on the location.

See the original technical documentation for each of these studies for additional information, maps, and results.

Determination of Base Hydrologic Model

The MATT reviewed results from previous modeling and decided to move forward with the 2014 Denver SDMP CUHP/SWMM analysis as the "Base Model" for the I-70 PCL analysis. This model was selected due to the fact that it is the latest model available and incorporates all previous analyses. A CUHP-UDSWMM routing schematic map representing this model is located in the appendix, which includes a summary of 100-year peak flow rates for each design point.

The base model was then modified for the I-70 project based on a series of sensitivity analyses performed by the MATT for the Montclair Basin. The sensitivity analysis accounted for potential modifications to modeling parameters that the group had identified as potentially more accurate, and also accounting for physical features observed within the basin that were not previously accounted for in the model. The results of this sensitivity analysis are discussed in the following section.

4.0 Hydrologic Modeling Sensitivity Analysis

In the Montclair basin, the MATT investigated several potential modifications to the base CUHP/UDSWMM modeling and performed a sensitivity analysis on each. After the sensitivity analysis was completed and modeling revisions were recommended, the MATT also recommended applying the same modifications to the Park Hill hydrologic modeling. Please refer to the accompanying *I-70 PCL MATT Montclair Basin Hydrology* technical memorandum for full documentation of the sensitivity analysis.

The location for comparing flow rates from a sensitivity analysis standpoint is at Smith Road and Dahlia Street. This location is represented as "Design Point JUNCT_630" in the modeling. Once water reaches Smith Road, it branches into several different directions and is conveyed by various underground pipes and multiple streets and railroad corridors. These diversions along and downstream (north) of Smith Road are accounted for in the Hydraulic modeling, and can be utilized by the I-70 designers to determine 100-year peak flow rates expected to reach I-70.

The following table summarizes comparative peak runoff rates and hydrographs for the modeling sensitivity analysis investigated by the MATT. In this basin, the MATT only made one modification to the base 2014 SDMP CUHP/SWMM models, which was to utilize the larger and more accurate multiple-street cross sections in the SWMM models. Again, see the Montclair basin memorandum for more information on this determination.

Park Hill Basin Hydrology – Sensitivity Analysis
100-Year Runoff at Smith Road and Dahlia Street

Model or Potential Modification*	Q100 (cfs)	Change from Base Model	Comment
2014 CCD Master Plan	**2733**	0%	**Base Model, CUHP-UDSWMM 2000, CUHP 2005, EPASWMM 5.0**
Multiple Street X-section Routing Elements	2600	-5%	Adjusted trapezoidal bottom width and side slopes
Inadvertent Detention in Park Hill Golf Course	NA		Not analyzed due to inability to reach agreement with Golf Course

* All models represent total peak runoff at Smith Road and Dahlia Street, Design Point JUNCT_630 for comparative purposes. All models account for existing detention at 38th & Holly.
Red = changes recommended by MATT

5.0 Revised I-70 PCL Hydrology Results and Final MATT Recommendations

Recommendations

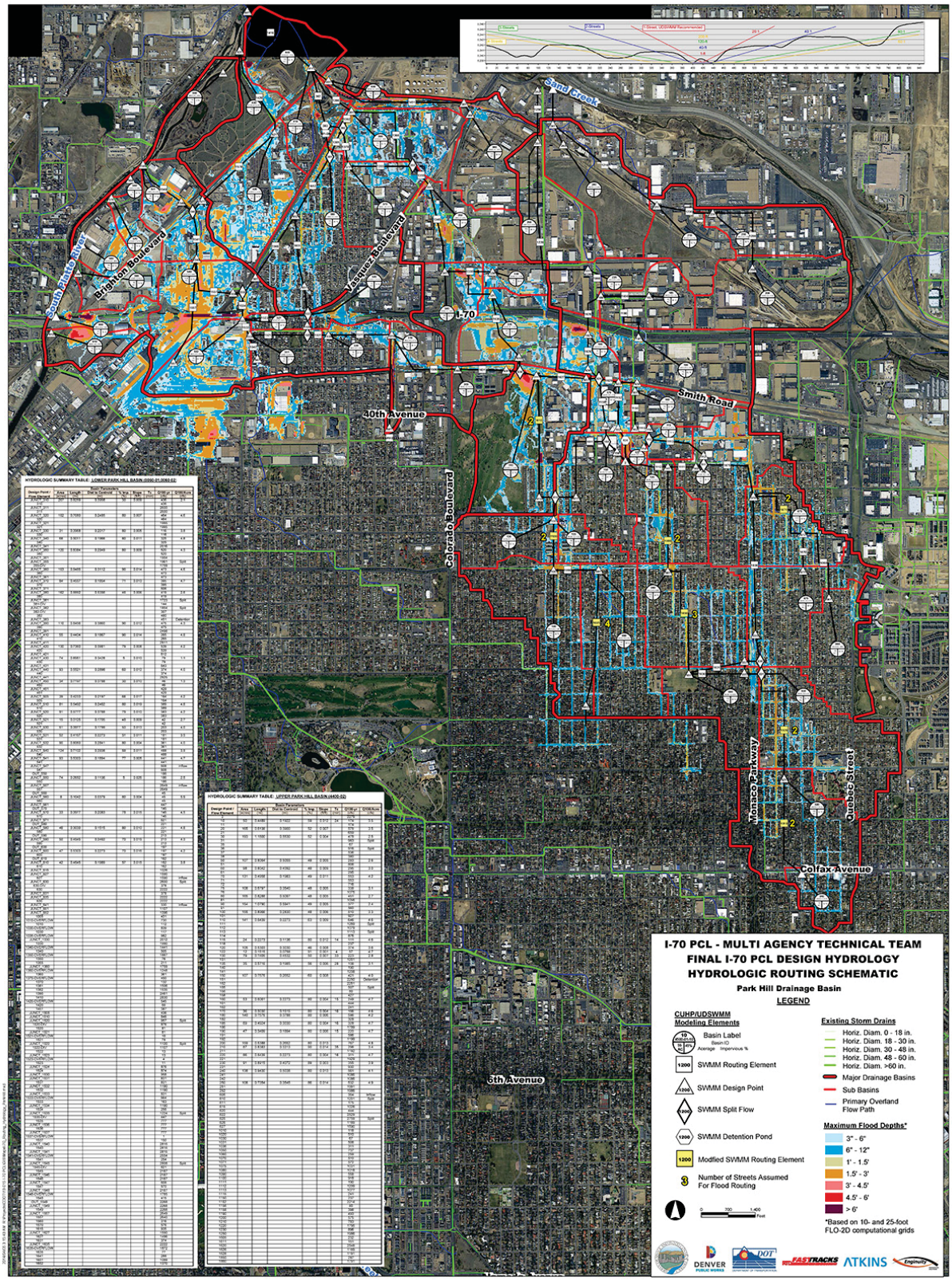
After reviewing the previous hydrologic studies performed for the Montclair and Park Hill drainage basins and further performing a sensitivity analysis of various modeling parameter modifications, the MATT has recommended the following modifications be made to the base 2014 SDMP CUHP/SWMM model for I-70 design purposes:

- Revise UDSWMM routing elements to more accurately represent flow occurring down multiple streets.

Results

Incorporating the MATT recommendations into the CUHP/SWMM hydrologic modeling for both the Monclair and Park Hill basins, revised 100-year peak flow rate were calculated at various points along I-70 and are summarized in the following table. This table includes runoff from both the Montclair and Park Hill basins. See the SWMM routing schematic in the Appendix for additional information and design point locations.

100-year Storm Peak Discharge Summary Based on MATT Hydrology* - Existing Conditions		
Design Point	Peak Discharge (cfs)	Location (Source)
557	2,649	I-70/Race (Montclair main stem)
1532	1,190	I-70/York (Montclair east + local basins)
1522	1,120	I-70/Steele (Montclair & Park Hill Market Lead + local basins)
321	1,995	I-70/Colorado (Park Hill main stem)
* Assumes High Street outfall is completed and accounts for inadvertent detention at the Duck Pond and City Park Golf Course		



This image represents the Park Hill basin's SWMM Routing diagram, a larger version is available in the appendix.

6.0 Appendix

All supporting maps, figures, tables, and hydrologic models used during the MATT analysis are provided in electronic format only. All supporting documentation can be found on the attached DVD.

The supporting documents are organized in the same general order to match the layout of this memorandum. Supporting documents include:

01. Figures/Maps/Tables:

- A. Background Montclair Mapping
    - i. Montclair/Park Hill Basin FLO-2D Flooding Depth Analysis
    - ii. 2008 RTD East Corridor CUHP-SWMM Routing Diagram
    - iii. 2014 SDMP Base Model CUHP-SWMM Routing Diagram
- B. Hydrology Sensitivity Analysis
    - i. Multiple Street SWMM Routing
- C. Final Hydrologic Mapping for I-70 PCL
    - i. Final MATT I-70 PCL CUHP-SWMM Routing Diagram

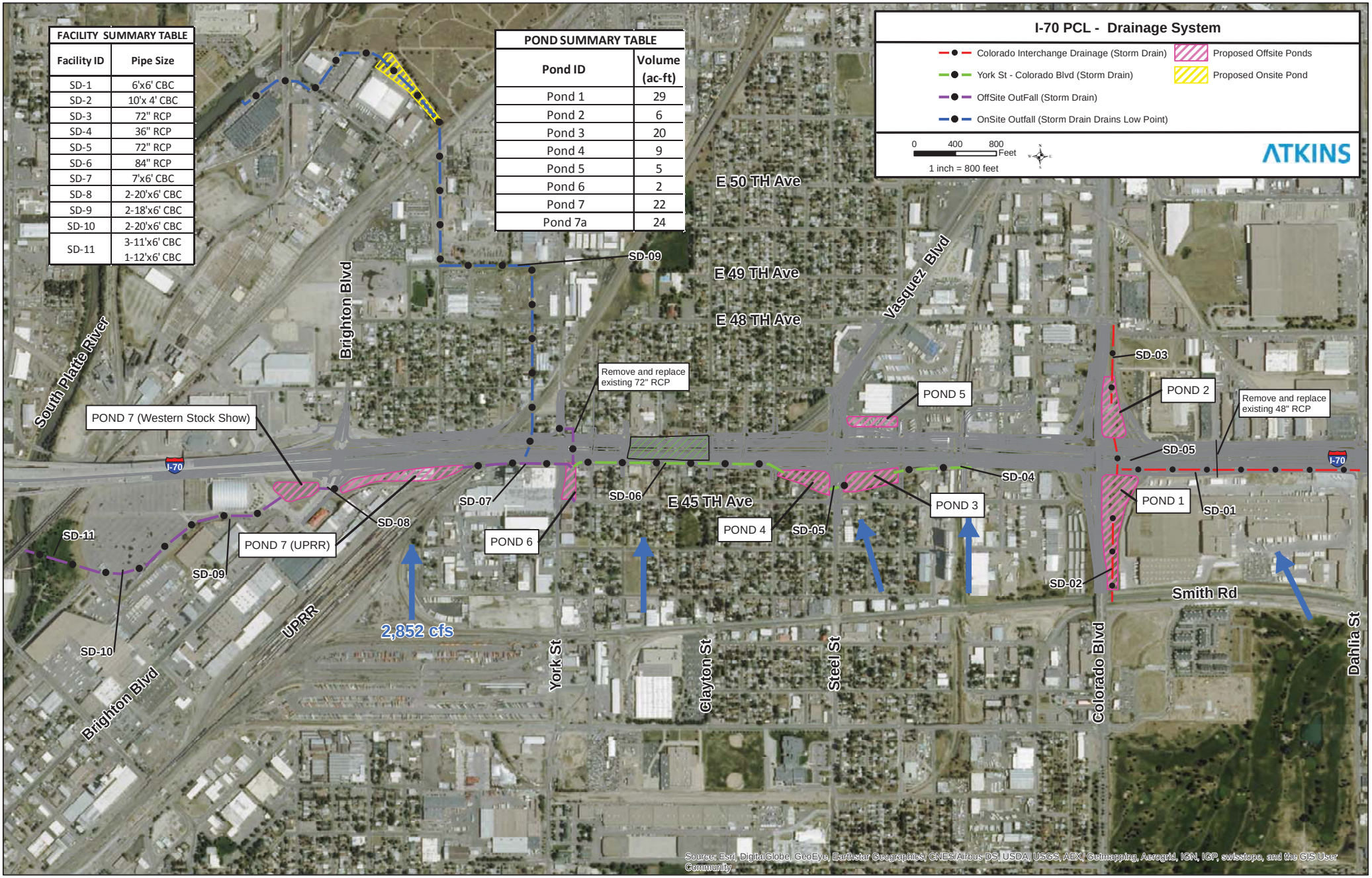
02. Hydrologic Models CUHP-UDSWMM:

- A. Previous Models
    - i. 2014 Denver SDMP
- B. Final Hydrology Revised for I-70 PCL
    - i. Multiple Street Routing

03. Peer Review of Analysis

04. MATT Meeting Minutes

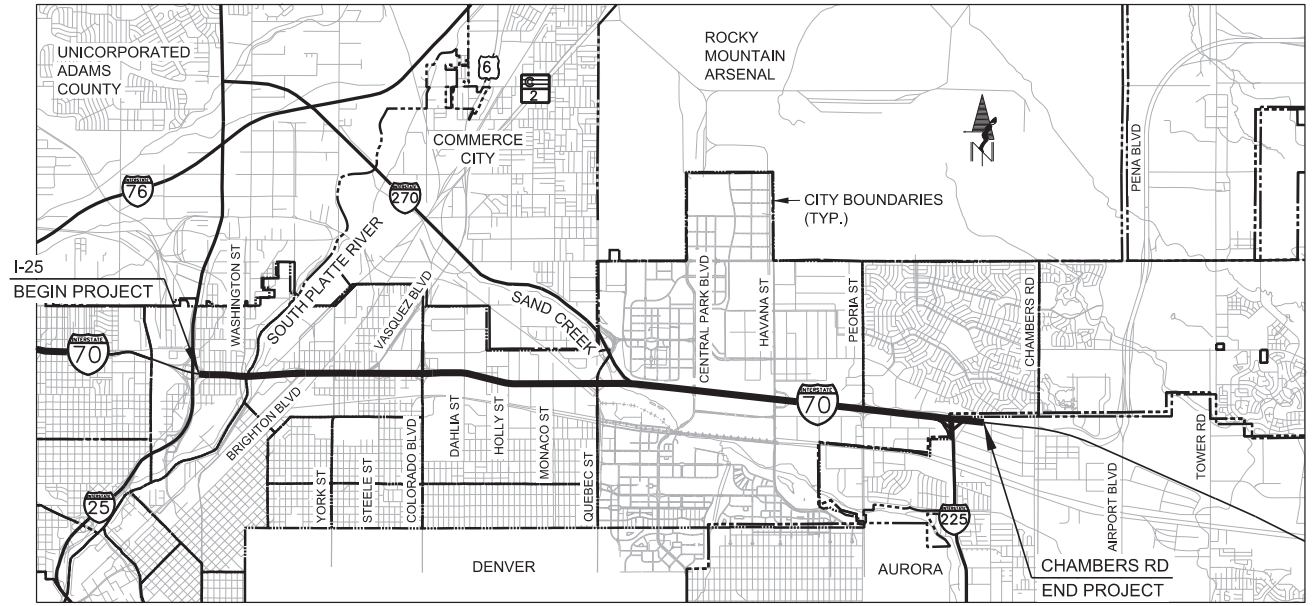
Attachment M – Appendix D.
Onsite and Offsite Drainage Plan and Profile Sheets (Update)


I-70 PCL - Drainage System
Colorado Interchange Drainage (Storm Drain)
York St - Colorado Blvd (Storm Drain)
OffSite OutFall (Storm Drain)
OnSite Outfall (Storm Drain Drains Low Point)
Proposed Offsite Ponds
Proposed Onsite Pond
0 400 800 Feet
1 inch = 800 feet
ATKINS
FACILITY SUMMARY TABLE
Facility ID | Pipe Size
SD-1 | 6'x6' CBC
SD-2 | 10'x 4' CBC
SD-3 | 72" RCP
SD-4 | 36" RCP
SD-5 | 72" RCP
SD-6 | 84" RCP
SD-7 | 7'x6' CBC
SD-8 | 2-20'x6' CBC
SD-9 | 2-18'x6' CBC
SD-10 | 2-20'x6' CBC
SD-11 | 3-11'x6' CBC 1-12'x6' CBC
POND SUMMARY TABLE
Pond ID | Volume (ac-ft)
Pond 1 | 29
Pond 2 | 6
Pond 3 | 20
Pond 4 | 9
Pond 5 | 5
Pond 6 | 2
Pond 7 | 22
Pond 7a | 24
E 50 TH Ave
E 49 TH Ave
E 48 TH Ave
E 45 TH Ave
Brighton Blvd
Vasquez Blvd
South Platte River
Remove and replace existing 72" RCP
Remove and replace existing 48" RCP
POND 7 (Western Stock Show)
POND 7 (UPRR)
POND 6
POND 4
POND 5
POND 3
POND 2
POND 1
SD-01
SD-02
SD-03
SD-04
SD-05
SD-06
SD-07
SD-08
SD-09
SD-10
SD-11
I-70
2,852 cfs
UPRR
York St
Clayton St
Steel St
Colorado Blvd
Smith Rd
Dahlia St
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

I-70 EAST

Environmental Impact Statement

FEIS PHASE 1 PLANS



The enclosed draft is considered preliminary for internal review only and shall not be shared with any person outside of your agency. Since this document is considered a working draft and it may contain preliminary conclusions not necessarily reflected in the final decision, all requests for any portion of this material should be denied under Exemption 5 of the Freedom of Information Act (FOIA) and the Department of Transportation implementing regulation (49 CFR 7.71). Any requests for materials from outside of your agency should be forwarded to FHWA or FTA.

DRAFT

SUBJECT TO CHANGE

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Last Modification Date: 10/20/2015 Initials: BEG		
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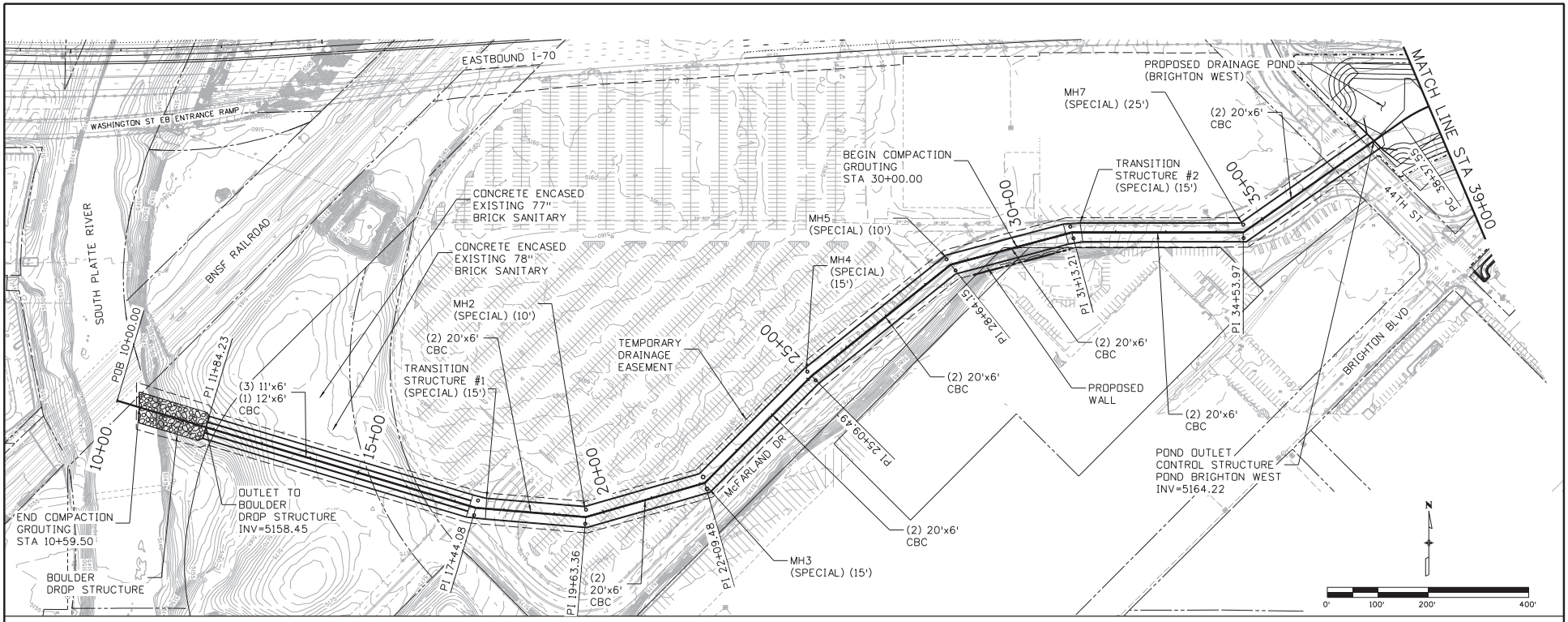

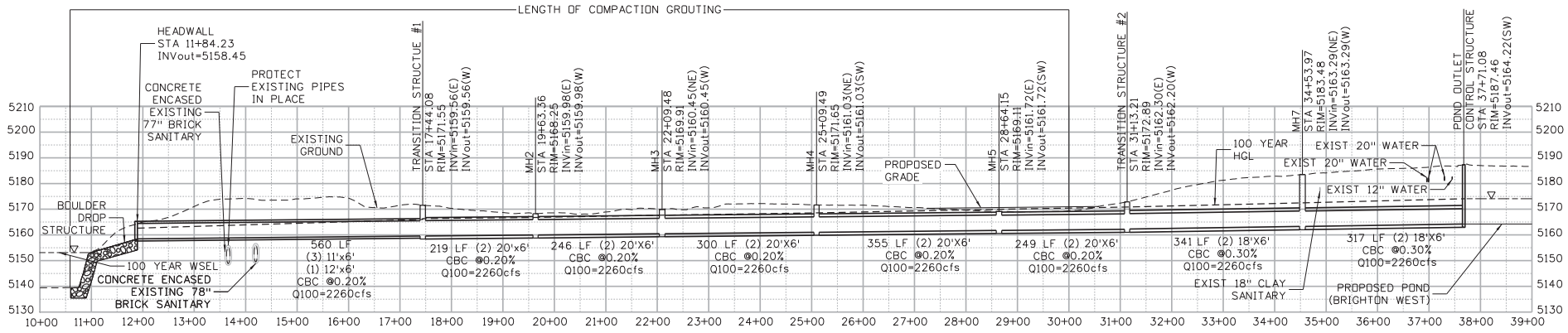

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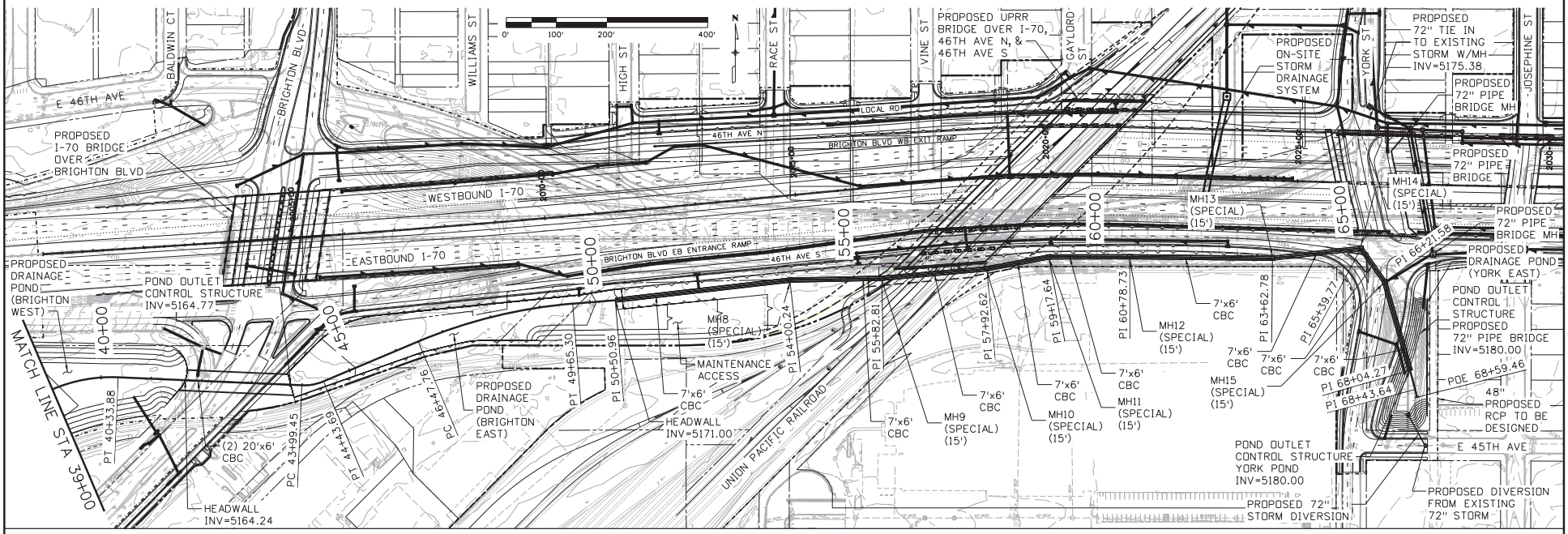

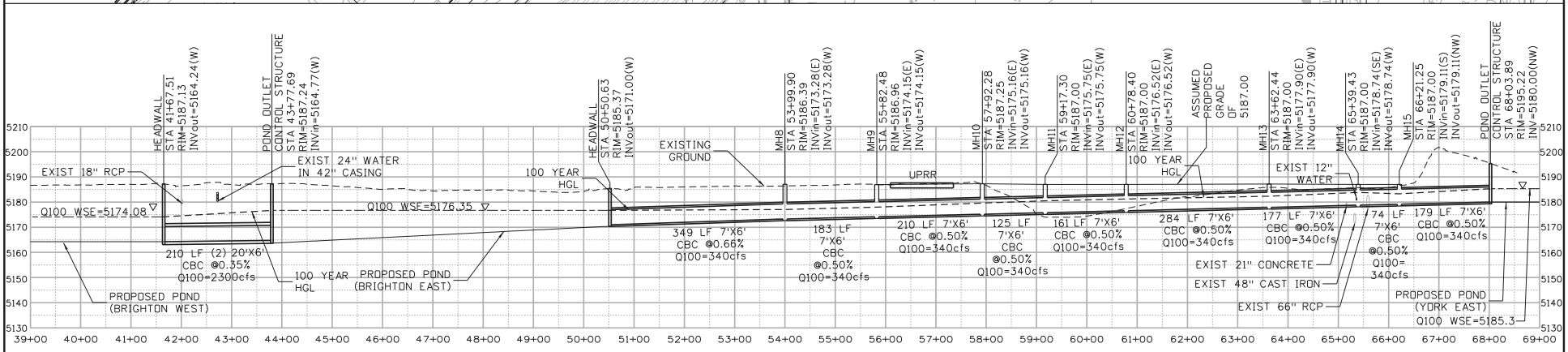

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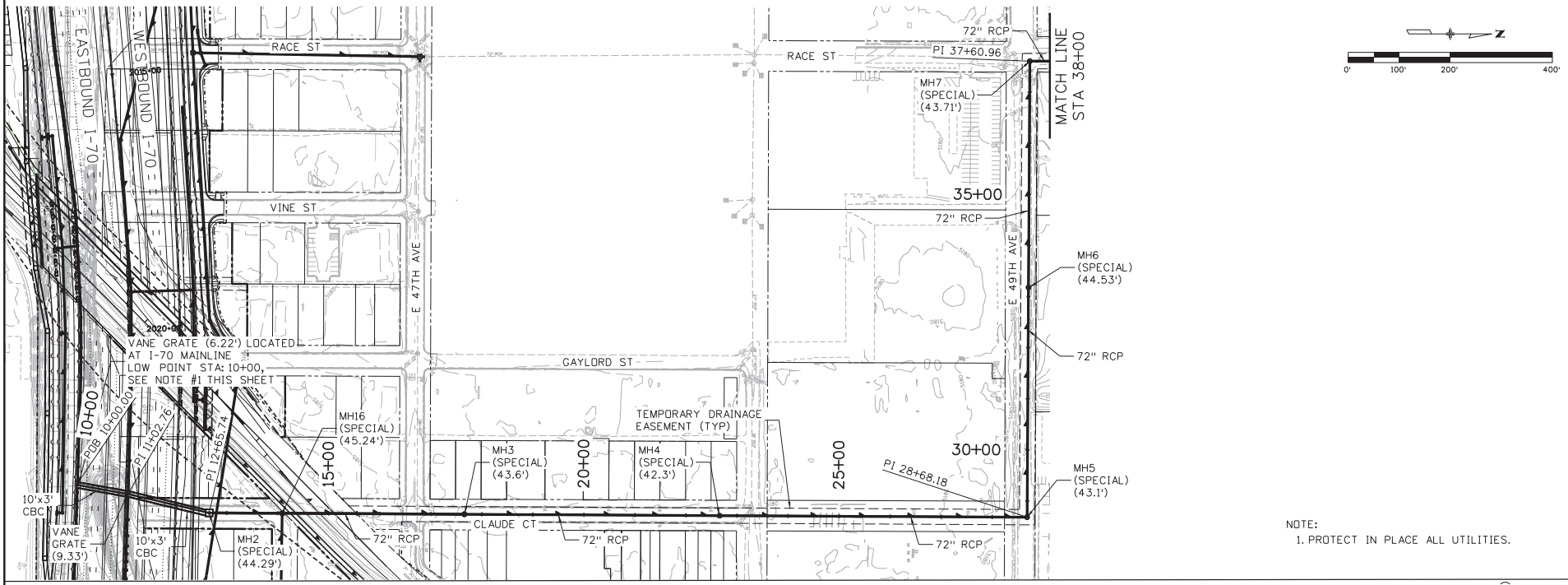

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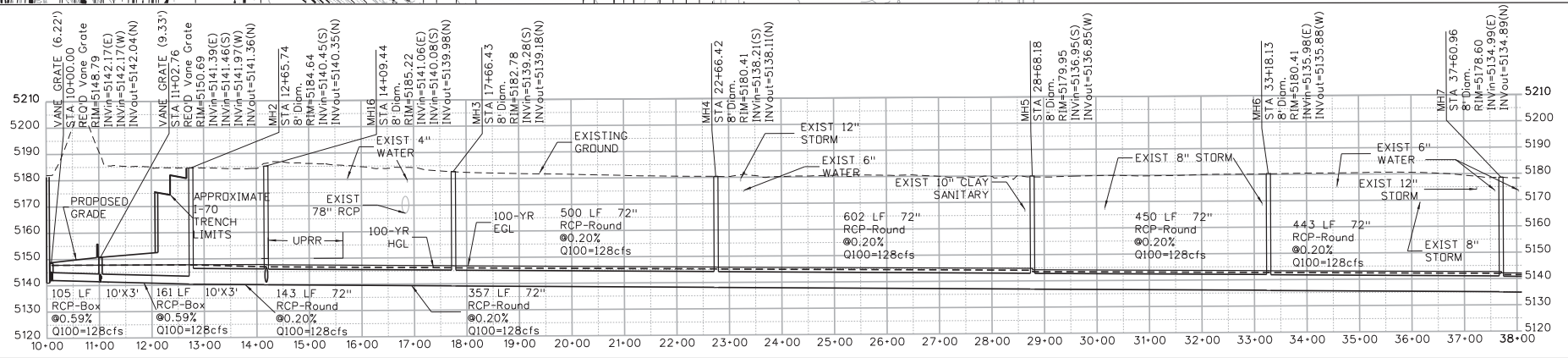

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I-70 LOWERED
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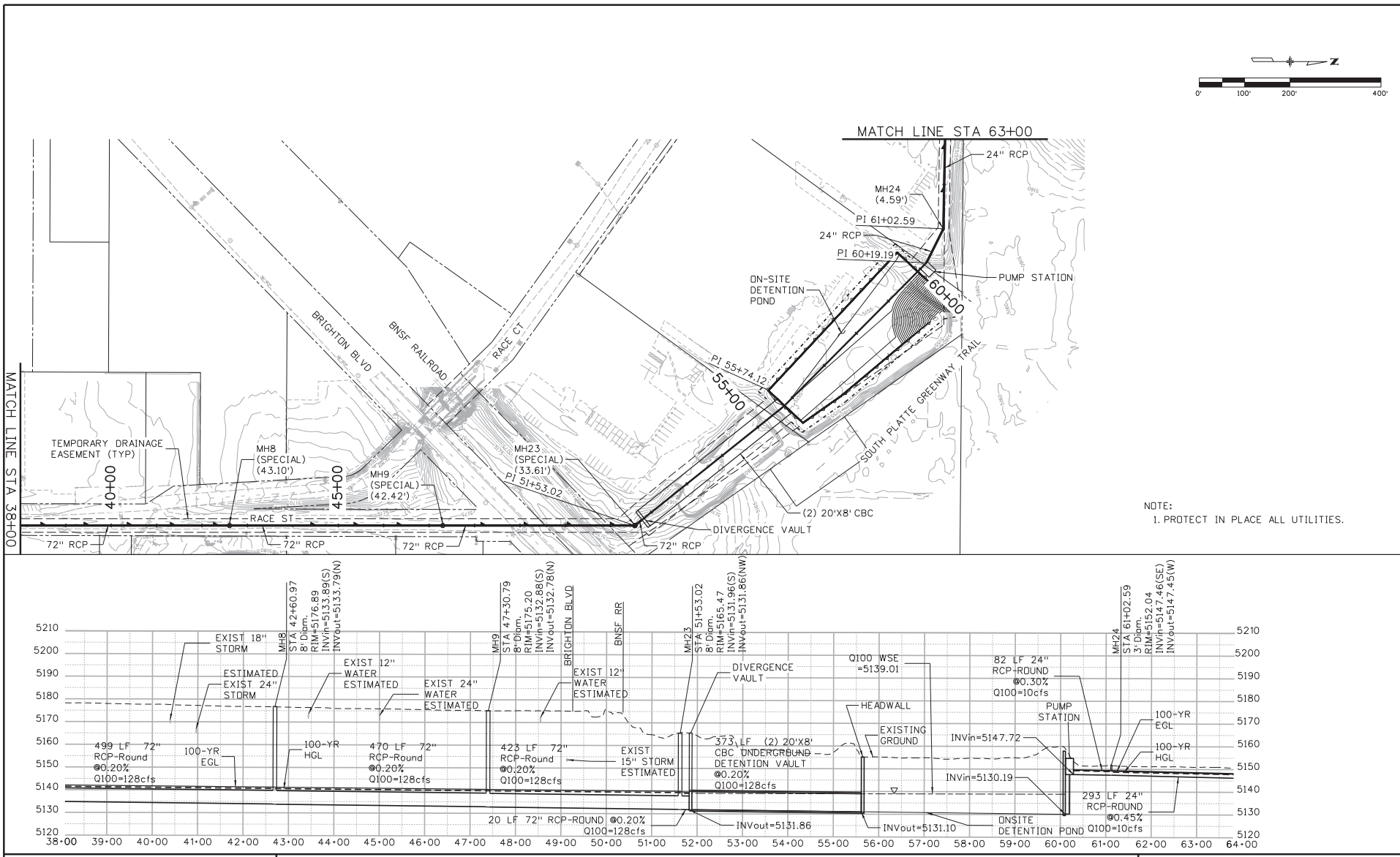
PLAN AND PROFILE
PARTIAL COVER LOWERED
MANAGED LANES
BRIGHTON BLVD TO COLORADO BLVD Sheet No: 4



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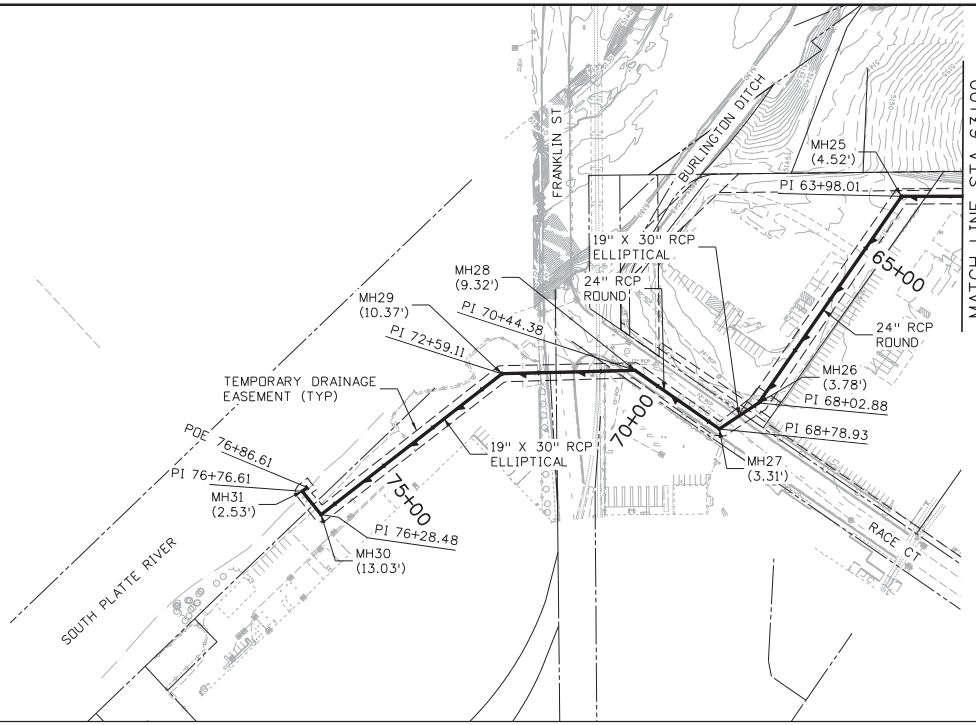

NOTE:
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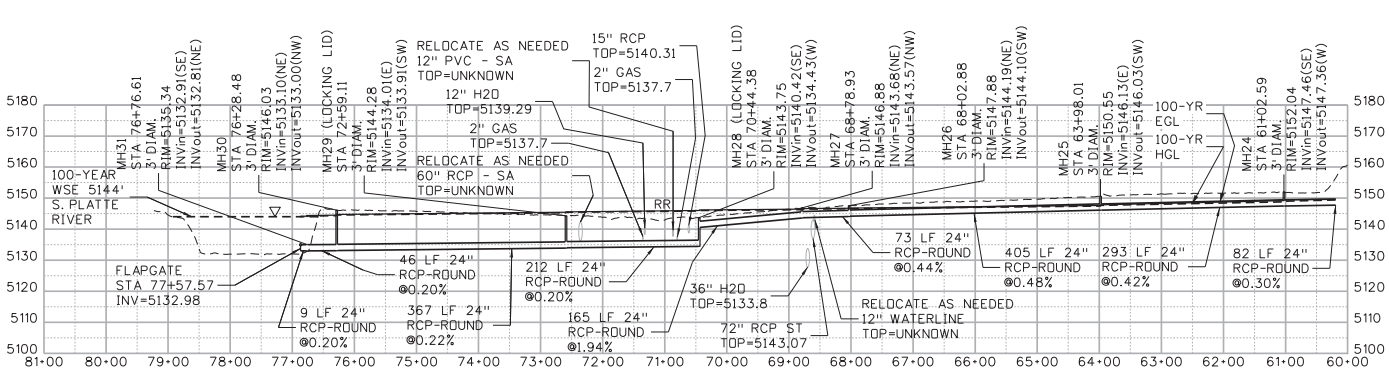

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